ESTUARINE HABITAT AND JUVENILE SALMON – CURRENT AND HISTORICAL LINKAGES IN THE LOWER COLUMBIA RIVER AND ESTUARY, 2003

By

G. Curtis Roegner, Daniel L. Bottom, Antonio Baptista[1], Susan Hinton,
Charles A. Simenstad[2], Edmundo Casillas, and Kim Jones[3]

Report of Research by
Fish Ecology Division
NOAA Fisheries
Northwest Fisheries Science Center
2725 Montlake Blvd. E.
Seattle, Washington 98112
to
Portland District
U.S. Army Corps of Engineers
333 S.W. First Avenue
Portland, Oregon 97208-2946

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[1] OGI School of Science & Engineering, Oregon Health and Science University, Beaverton, OR
[2] School of Aquatic and Fisheries Science, University of Washington, Seattle, WA
[3] Oregon Department of Fish aNd Wildlife, Corvallis, OR

EXECUTIVE SUMMARY

In 2003, we continued a monthly beach seine monitoring program at seven sites in the lower Columbia River and estuary and sampled over 39,000 fish, including 2,091 chinook salmon. We also continued a trapnet program at three replicate sites within Cathlamet Bay for detailed emergent wetland assessments of salmon-habitat linkages. Nearly 174,000 total fish and 839 chinook were sampled. At all sites, we collected salmon fin clips, stomachs, scales, and otoliths to evaluate salmonid growth and life history, and at wetland sites we additionally sampled insects from fallout traps and benthic organisms from sediment cores to monitor prey resources. Analysis of stomach samples from widely disparate beach seine sites suggests juvenile salmon were feeding throughout the examined range. In freshwater, fish were feeding mainly on insects and benthic amphipods, while for fish in the estuary the diet expanded to include fish and crab larvae. At trapnet sites, salmon fed mainly on insects, but there were differences in abundances between sites that were probably related to vegetation type. Genetic and otolith samples are currently being analyzed. Physical conditions throughout the lower river and estuary were measured continuously at a network of fixed monitoring stations (CORIE) and within selected marsh habitats with temperature loggers. We also used a conductivity-temperature-depth (CTD) instrument to sample physical conditions during the monthly fish surveys at all beach seine sites in the study region. The physical measurements reveal strong variation in all parameters over the measured spatial and temporal scales.

INTRODUCTION

Estuaries are considered important to rearing of juvenile salmon and represent an integral component of the continuum of habitats that salmon occupy for significant periods of time. There is, however, a general lack of science-based information concerning attributes of these tidal freshwater and oligohaline transition zones needed to support juvenile salmon, particularly in the lower Columbia River and estuary. Further, recent evidence supports the concern that flow in the Columbia River significantly affects the availability of estuarine habitats, that flow is much reduced compared to historical levels, and that seasonal flow patterns are much different now than a century ago. The long history of wetland loss in the Columbia River estuary coupled with change in flow patterns suggests that restoration of these habitats may benefit recovery of depressed salmon stocks. The development of effective restoration strategies requires empirical data for habitat-salmon linkages in the lower Columbia River and estuary. This research report documents results from our second full year's effort to understand these linkages.

Accomplishments in 2003 include (1) continuation of a monthly beach seine monitoring program at seven sites in the lower Columbia River and estuary since December 2001, (2) continued trapnet sampling at three replicate sites for detailed emergent wetland assessments of salmon-habitat linkages in Cathlamet Bay, (3) deployment of a physical monitoring system in the Cathlamet Bay region, augmented with additional physical measurements made at beach seine and trapnet sites, that together complement the existing network of real-time physical monitoring stations in the Columbia River estuary (CORIE). Details of these research findings are summarized below.

PROGRESS TO DATE

Objective 1. Compare trends in abundance and life histories of juvenile salmon at a landscape scale on representative shallow habitats between Puget Island and the Columbia River mouth.

1.1 Selected beach seine sites

Seven beach seine sites have been sampled monthly since December 2001 (Figure 1). The locations include two sites in the ocean-influenced zone near the mouth of the Columbia River (Lower Estuary sites; Clatsop Spit and West Sand Island), two sites near the salt-freshwater interface (Upper Estuary sites; Pt. Ellice and Pt. Adams Beach), and three sites in the tidal freshwater zone at the upriver end of Cathlamet Bay (Lower Elochoman Slough, East Tenasillahe Island, and Upper Clifton Channel).

1.2 Monitor fish habitat use along selected transects

Fish species composition was sampled with a 50-m variable mesh (19.0-, 12.7-, and 9.5-mm) beach seine with knotless web in the bunt to reduce descaling. During deployment, one end of the seine was anchored on the beach while the other was towed by a skiff to enclose a ~2500 m^2 semicircular area. We sorted the catch on site. For non-salmonid species, we measured (nearest 1.0 mm), weighed (nearest 0.1 g), and released a representative sample (30 individuals) of each species. All other non-salmonids were counted and released. For salmonids, we sacrificed a maximum of ten individuals of each species and size class for genetic, stomach, scale, and otolith samples. In addition, we measured and weighed 20 individuals of each

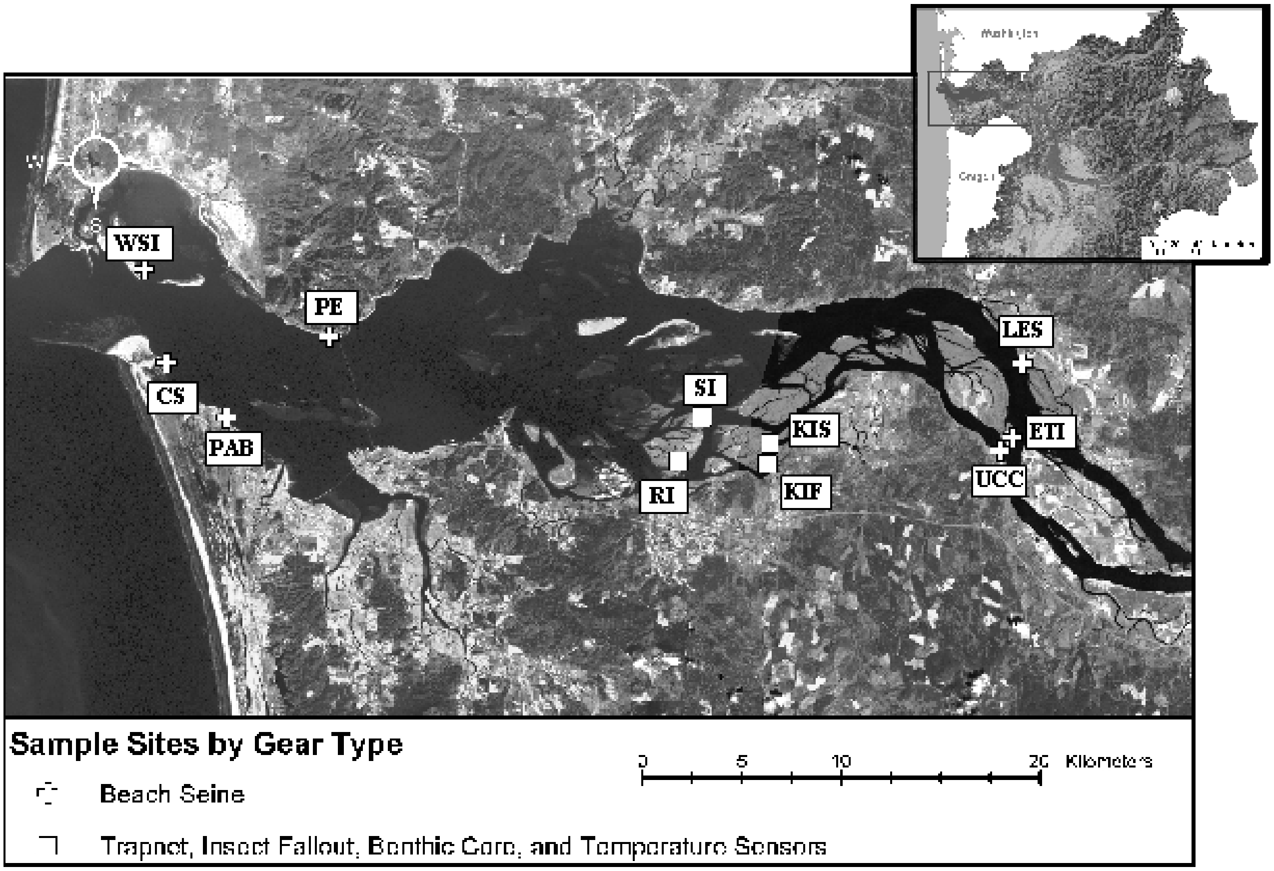

Figure 1. Lower Columbia River and estuary study site, showing beach seine and trapnet locations. Inset shows regional setting. Beach seine sites: WSI, West Sand Island; CS, Clatsop Spit PE, Pt. Ellice; PAB, Pt. Adams Beach; LES, Lower Elochoman Slough; ETI, East Tenasillahe Island; UCC, Upper Clifton Channel. Trapnet sites; SI, Seal Island; RI, Russian Island; KIS. Karlson Island – shrub; KIF, Karlson Island – forested.

salmonid species and size class prior to release and retained non-lethal tissue and scale samples for genetic and age/growth analyses, respectively.

In 2003, we collected 42 species of fishes totaling over 39,000 individuals (Tables 1-8). Of these, 22 species had a total abundance greater than 10, and the following summary is compiled from these more abundant species. Sixty-eight percent (26,670 individuals) of all fish sampled were threespine sticklebacks (*Gasterosteus aculeatus*) (Table 9). The next five most abundant fish were shiner perch (*Cymatogaster aggregata*), surf smelt (*Hypomesus pretiosus*), chinook salmon (*Oncorhynchus tshawytscha*), starry flounder (*Platichthys stellatus*), and American shad (*Alosa sapidissima*), respectively. Fish species compositions were similar between stations within zones, but varied significantly among zones (Figure 2). Species composition within the various sample regions followed four general patterns (Table 9): lower estuarine species (4); estuarine species (7); freshwater species (5); and euryhaline or anadromous species (5). We assume salinity tolerance to be a major determinant of these spatial patterns. Temporal trends included resident, seasonal, and episodic patterns of abundance.

Chinook salmon were found during all months of the year. We sampled 2091 chinook, and, based on size frequency histograms, subyearling fish dominated the catch (Figure 2). Trends of chinook salmon abundance varied among river sections. Fish at the freshwater sites were abundant from February through August, but the timing of peak catches varied between stations. In the estuary, chinook salmon were abundant May through August, with peaks in May (PAB) or July (other stations). Mean size of chinook generally increased with time, with the exception of increased mean and variance in some April or May samples due to the presence of yearling fish (Figure 3). However, the size distribution varied between estuarine and freshwater sites. After July, estuarine fish tended to be larger than fish caught in the freshwater zone.

In contrast to chinook, coho (*Oncorhynchus kisutch*) and chum (*O. keta*) salmon abundances were restricted both spatially and temporally. We sampled only 11 coho salmon in 2003, and all but one was captured in May. Too few coho were caught for meaningful size-frequency determination. We sampled 284 chum salmon, of which 94% were found at estuarine stations. Chum salmon were present from February to May (Figure 5), with peak abundance in February (Upper Estuary) or April (Lower Estuary). The largest chum were generally found in May (Figure 5).

Table 1. Common and scientific names of fish species captured in beach seine and trapnet samples in 2003.

Common Name	**Scientific Name**
American shad	*Alosa sapidissima*
Banded killifish	*Fundulus diaphanus*
Bay pipefish	*Syngnathus leptorhynchus*
Black crappie	*Pomoxis nigromaculatus*
Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Common carp	*Cyprinus carpio*
Cutthroat trout	*Oncorhynchus clarki*
Dungeness crab	*Cancer magister*
English sole	*Parophrys vetulus*
Eulachon	*Thaleichthys pacificus*
Largemouth bass	*Micropterus salmoides*
Largescale sucker	*Catostomus macrocheilus*
Longfin smelt	*Spirinchus thaleichthys*
Northern anchovy	*Engraulis mordax*
Northern pikeminnow	*Ptychocheilus oregonensis*
Pacific herring	*Clupea harengus pallasi*
Pacific sand lance	*Ammodytes hexapterus*
Pacific sanddab	*Citharichthys sordidus*
Pacific sardine	*Sardinops sagax*
Pacific staghorn sculpin	*Leptocottus armatus*
Pacific tomcod	*Microgadus proximus*
Peamouth	*Mylocheilus caurinus*
Prickly sculpin	*Cottus asper*
Rainbow trout (steelhead)	*Oncorhynchus mykiss*
Redtail surfperch	*Amphistichus rhodoterus*
River lamprey	*Lampetra ayresi*
Saddleback gunnel	*Pholis ornata*
Sand roller	*Percopsis transmontana*
Sand sole	*Psettichthys melanostictus*
Shiner perch	*Cymatogaster aggregata*
Snake prickleback	*Lumpenus sagitta*
Sockeye salmon	*Oncorhynchus nerka*
Speckled sanddab	*Citharichthys stigmaeus*
Starry flounder	*Platichthys stellatus*
Surf smelt	*Hypomesus pretiosus*
Threespine stickleback	*Gasterosteus aculeatus*
Topsmelt	*Atherinops affinis*
Walleye surfperch	*Stizostedion vitreum*
Whitebait smelt	*Allosmerus elongatus*
Yellow perch	*Perca flavescens*

Table 2. Abundance of species sampled by beach seine at West Sand Island during 2003.

Species	**Jan03**	**Feb03**	**Mar03**	**Apr03**	**May03**	**Jun03**	**Jul03**	**Aug03**	**Sep03**	**Oct03**	**Nov03**	**Dec03**	**Total**
Banded killifish							1						1
Chinook salmon		2	6	3	17	10	9	14	8	2			71
Chum salmon		2	123	13	28								166
Dungeness crab							2	3	114	3			122
English sole	2	9	2	2		4							19
Northern anchovy							1		23	2			26
Pacific herring									174				174
Pacific sardine									16	27			43
Pacific staghorn sculpin	17	21	3	2		1			1	3			48
Saddleback gunnel							1						1
Sand sole	5	3			1	7	11	6	5	6	2		46
Shiner perch							93						93
Speckled sanddab						1					1		2
Starry flounder	4		1		1	5	16			3	1		31
Surf smelt	1		56	20	283	47	105	19	299	3			833
Threespine stickleback	10	1	1	4		12	19	13	1				61
Unid. Pleuronectidae			7	42	64	3	1		5				122
Unidentified juv. smelt			119										119
Total	39	38	318	86	394	90	259	55	646	49	4		1978

Table 3. Abundance of species sampled by beach seine at Clatsop Spit during 2003. ND; Not done.

Species	**Jan03**	**Feb03**	**Mar03**	**Apr03**	**May03**	**Jun03**	**Jul03**	**Aug03**	**Sep03**	**Oct03**	**Nov03**	**Dec03**	**Total**
Chinook salmon	3		3	7	13	21	8	32	8	1			96
Chum salmon			39		2								41
Coho salmon	1				1								2
Dungeness crab	2			1	4	1			1				9
English sole	1	1		1	2	1							6
Northern anchovy							1						1
Pacific herring						3			3	1			7
Pacific sand lance		1											1
Pacific staghorn sculpin		3	4			1				1		1	10
Prickly sculpin	1												1
Rainbow trout												1	1
River lamprey					1								1
Sand sole	3	4		8	1		1		2	2		1	22
Shiner perch						1	7		2	12			22
Sockeye salmon					1								1
Starry flounder	1		4	1	2		4		1	8		4	25
Surf smelt	21	13	4	22	33	174	40	319	120	73		1	820
Threespine stickleback	33	50	6	160	130	70	62	15	470	175		163	1334
Topsmelt										8			8
Unid. Pleuronectidae				18	1	2							21
Unidentified juv. smelt		5											5
Total	66	77	60	218	191	274	123	366	607	281	ND	171	2434

Table 4. Abundance of species sampled by beach seine at Pt. Ellice during 2003.

Species	**Jan03**	**Feb03**	**Mar03**	**Apr03**	**May03**	**Jun03**	**Jul03**	**Aug03**	**Sep03**	**Oct03**	**Nov03**	**Dec03**	**Total**
American shad				1									1
Banded killifish											2		2
Black crappie	3												3
Chinook salmon	1	15		75	11	11	39	30		1			183
Chum salmon		17		2									19
Dungeness crab					2		2	1	3				8
English sole	2	69		3									74
Pacific herring							15	4					19
Pacific sardine										8			8
Pacific staghorn sculpin	10	35		43	45	44	30	16	4	1	2		230
Pacific tomcod	1									2			3
Peamouth				1									1
Prickly sculpin											1		1
Rainbow trout				1									1
Saddleback gunnel							1						1
Sand sole		1			1					1			3
Shiner perch						17	981	804	47	38			1887
Starry flounder	19	35		19	5	47	210	71	39	32	23		500
Surf smelt	10	1					43	20					74
Threespine stickleback	409	11		5	40	111	44	19	84	24	3		750
Topsmelt										3			3
Unid. Pleuronectidae	1										2		3
Unidentified juv. smelt	1												1
Total	457	184	ND	150	104	231	1365	965	177	110	33	ND	3776

Table 5. Abundance of species sampled by beach seine at Pt Adams Beach during 2003.

Species	**Jan03**	**Feb03**	**Mar03**	**Apr03**	**May03**	**Jun03**	**Jul03**	**Aug03**	**Sep03**	**Oct03**	**Nov03**	**Dec03**	**Total**
American shad			1			3	6						10
Chinook salmon	1	36	16	35	42	80	180	10	10	9			419
Chum salmon		30	2	6	1								39
Dungeness crab			1							1			2
English sole		19	30	24	2	8	13						96
Northern anchovy							77			2		2	81
Pacific herring						3	1						4
Pacific sardine							1			2			3
Pacific staghorn sculpin		1	1		3	14	16	1	1	2			39
Prickly sculpin						1							1
Rainbow trout			1		2								3
Saddleback gunnel							8	1					9
Sand sole	1												1
Shiner perch						79	1419	286	78	156			2018
Speckled sanddab		2											2
Starry flounder	4	4	3	7	4	3	7		7	19		244	302
Surf smelt	46	112	7	242	4	93	9	2		13		101	629
Threespine stickleback	146	159	4700	699	63	146	143	16	2	39		1566	7679
Unid. Pleuronectidae	2			19	1	1							23
Unidentified fish												1	1
Unidentified Irish lord				1									1
Unidentified juv. smelt	1	127											128
Total	201	490	4762	1033	122	431	1880	316	98	243		1914	11490

Table 6. Abundance of species sampled by beach seine at Lower Elochoman Slough during 2003.

Species	Jan03	Feb03	Mar03	Apr03	May03	Jun03	Jul03	Aug03	Sep03	Oct03	Nov03	Dec03	Total
American shad						20	2	339	153	2		1	517
Banded killifish							2				1	1	4
Chinook salmon	19	98	130	48	97	130	82	16	4	14		3	641
Chum salmon			1	3	6								10
Coho salmon					1							7	8
Peamouth						9	4	68	7	5	1		94
Prickly sculpin				2									2
Starry flounder	6	15	10	9	2	1	2	6	3	2	4	5	65
Threespine stickleback	128	183	1716	1076	418	459	6380	77	70	94	171	134	10906
Total	153	296	1857	1138	524	619	6472	506	237	117	177	151	12247

Table 7. Abundance of species sampled by beach seine at East Tenasillahe Island during 2003.

Species	Jan03	Feb03	Mar03	Apr03	May03	Jun03	Jul03	Aug03	Sep03	Oct03	Nov03	Dec03	Total
American shad					2		1	23	4	4	1		35
Banded killifish							4	1			8		13
Chinook salmon	2	7	20	44	47	29	8	1	3	8	6	7	182
Chum salmon			1	5									6
Largescale sucker								1					1
Northern pikeminnow								1	1				2
Pacific staghorn sculpin		1											1
Peamouth							7						7
Rainbow trout				1	3								4
Sockeye salmon					1								1
Starry flounder	5	9	3	1	2		2		1		1	1	26
Threespine stickleback	2	4	1582	49	32	187	422	34	19	31	4		2366
Total	9	21	1606	100	87	217	444	61	28	44	20	8	2645

Table 8. Abundance of species sampled by beach seine at Upper Clifton Channel during 2003.

Species	**Jan03**	**Feb03**	**Mar03**	**Apr03**	**May03**	**Jun03**	**Jul03**	**Aug03**	**Sep03**	**Oct03**	**Nov03**	**Dec03**	**Total**
American shad						10		13	104	66			193
Banded killifish										1	2		3
Chinook salmon	5	32	61	51	164	91	61	16	9	7	1	1	499
Chum salmon				1	2								3
Coho salmon					1								1
Eulachon		1											1
Largescale sucker				1			1		2				4
Northern pikeminnow							2	12					14
Pacific staghorn sculpin		1											1
Peamouth				1	1	22	10	167	9	6			216
Prickly sculpin			1			3	6	29	2		1		42
Starry flounder	13	13	10	2	6	15	24	7		1	3	5	99
Threespine stickleback	217	965	387	76	243	749	516	205	152	6	31	27	3574
Yellow perch						1							1
Total	235	1012	459	132	417	891	620	449	278	87	38	33	4651

Table 9. Regional distribution of the 22 most common species sampled by beach seine.

Species	Lower estuary		Upper estuary		Freshwater				
	WSI	CS	PE	PAB	LES	ETI	UCC	Total	%
American shad			1	10	517	35	193	756	1.93
Banded killifish	1		2		4	13	3	23	0.06
Chinook salmon	71	96	183	419	641	182	499	2091	5.34
Chum salmon	166	41	19	39	10	6	3	284	0.72
Coho salmon		2			8		1	11	0.03
Dungeness crab	122	9	8	2				141	0.36
English sole	19	6	74	96				195	0.50
Northern anchovy	26	1		81				108	0.28
Northern pikeminnow						2	14	16	0.04
Pacific herring	174	7	19	4				204	0.52
Pacific sardine	43	1	8	3		1	1	57	0.15
Pacific staghorn sculpin	48	10	230	39				327	0.83
Peamouth			1		94	7	216	318	0.81
Prickly sculpin		1	1	1	2		42	47	0.12
Saddleback gunnel	1			9				10	0.03
Sand sole	46	22	3	1				72	0.18
Shiner perch	93	22	1887	2018			1	4021	10.26
Starry flounder	31	25	500	302	65	26	99	1048	2.67
Surf smelt	952	825	75	757				2609	6.66
Threespine stickleback	61	1334	750	7679	10906	2366	3574	26670	68.06
Topsmelt		8	3					11	0.03
Unid. Pleuronectidae	122	21	3	23				169	0.43
Total	1976	2432	3768	11486	12247	2643	4650	39188	100.00

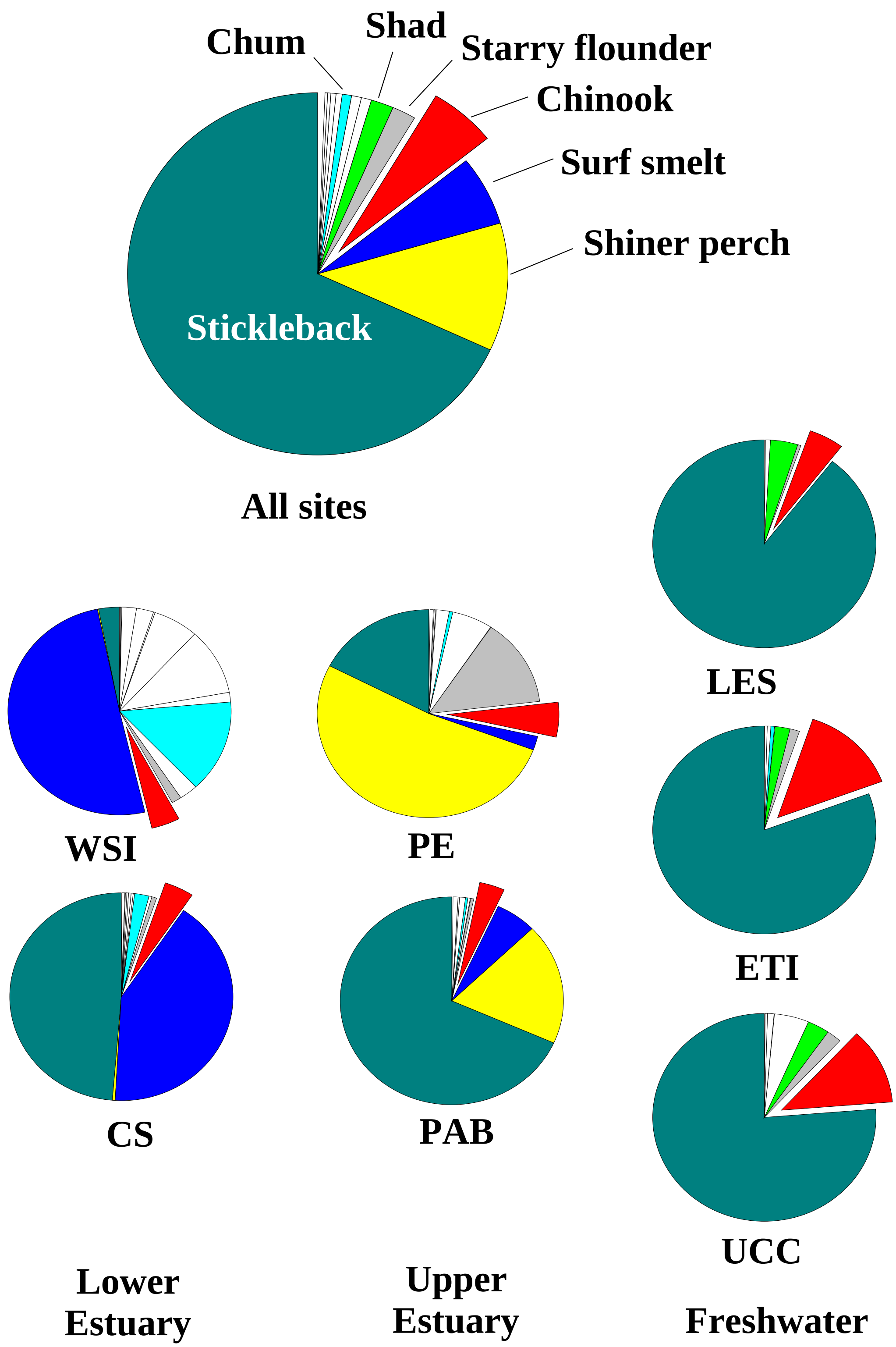

Figure 2. Proportional species composition of fishes sampled with beach seines at lower estuarine (WSI, CS), upper estuarine (PE, PAB), and freshwater stations (LES, ETI, UCC) during 2003

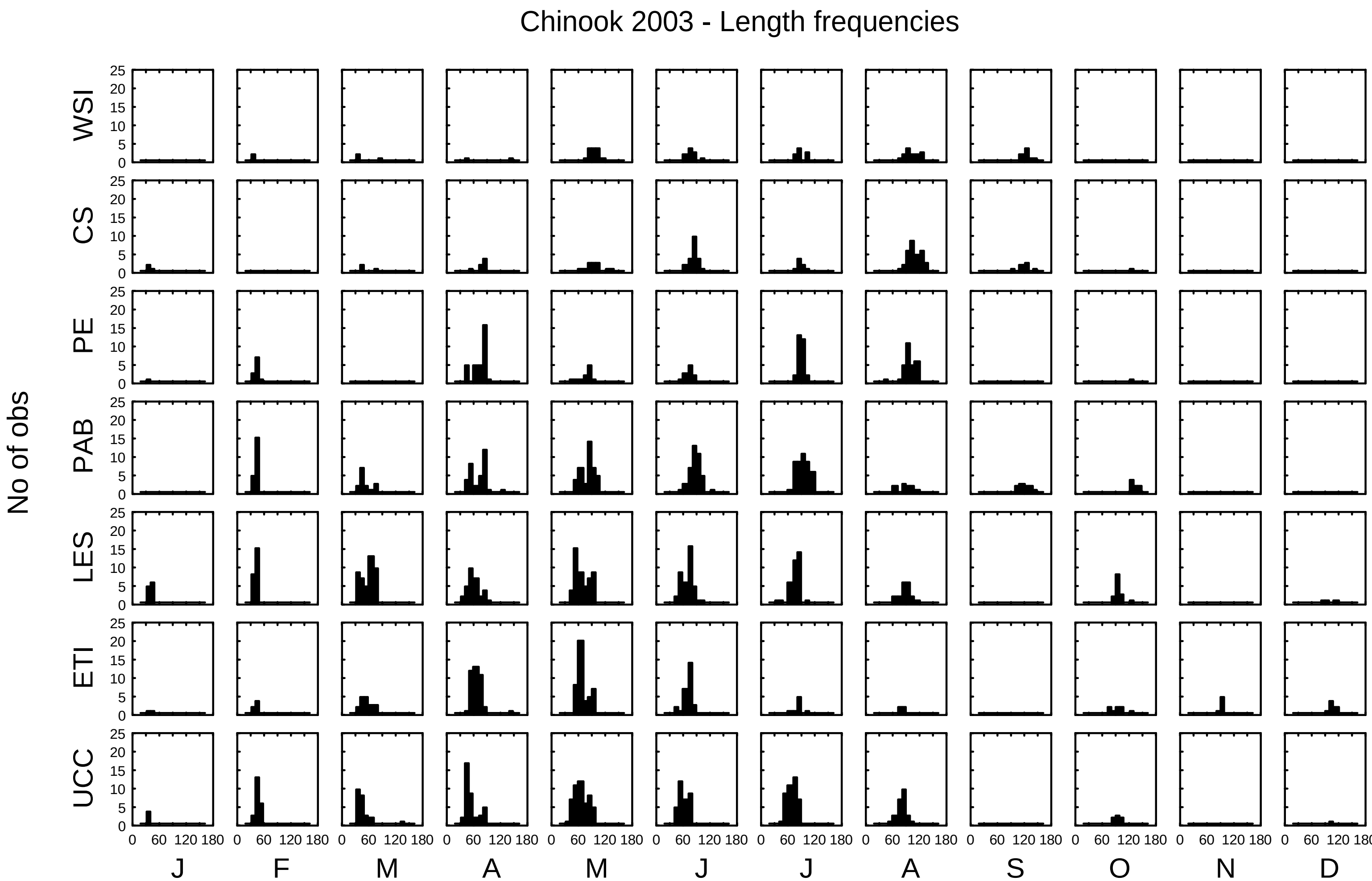

Figure 3. Monthly size frequency histograms reported as catch per unit effort (CPUE) of chinook salmon sampled with beach seines at lower estuarine (WSI, CS), upper estuarine (PE, PAB), and freshwater stations (LES, ETI, UCC) during 2003

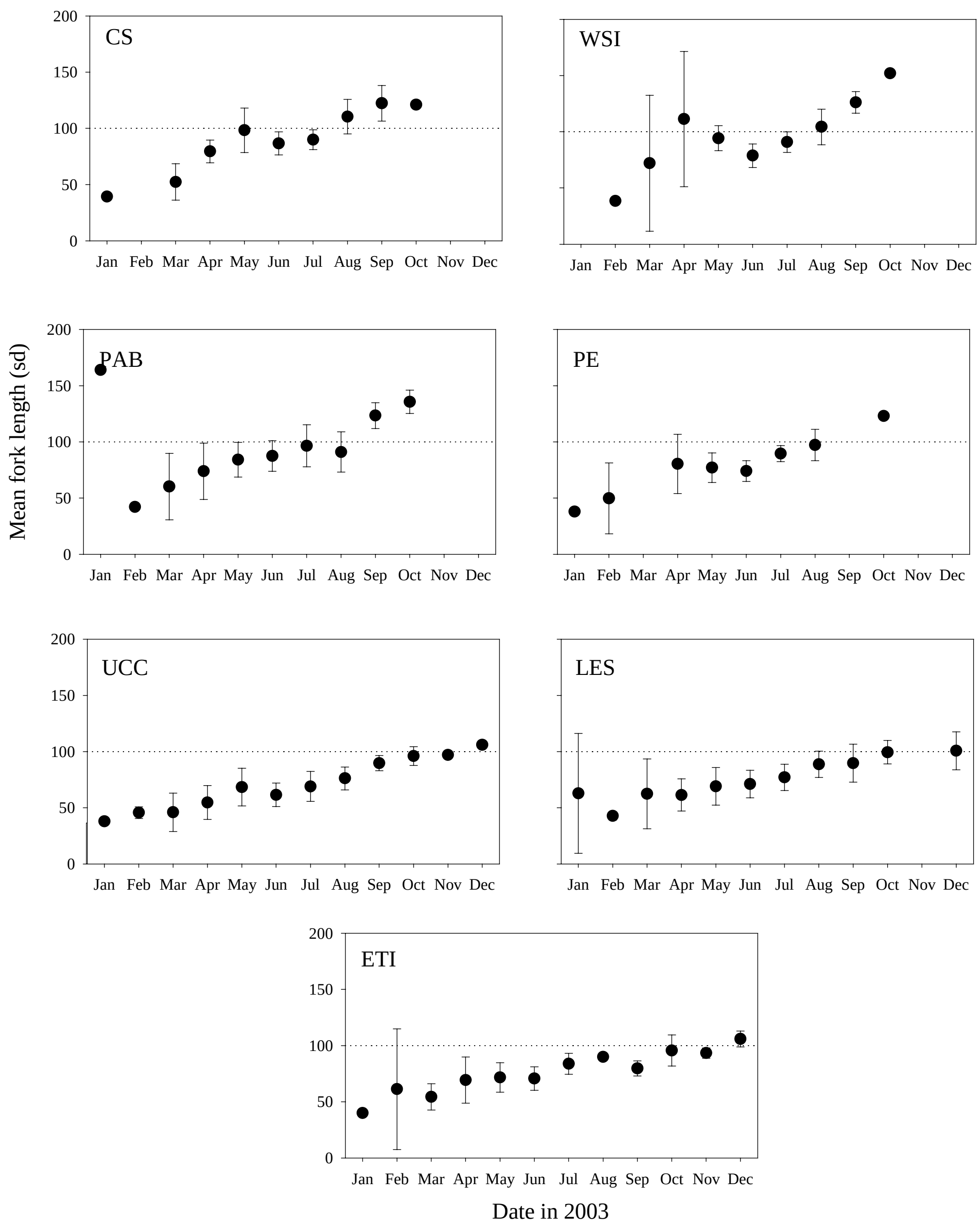

Figure 4. Time series of mean fork length (+ SD) of chinook salmon sampled with beach seines at lower estuarine (WSI, CS), upper estuarine (PE, PAB), and freshwater stations (LES, ETI, UCC) during 2003. Dashed line at 100 mm is for comparative purposes.

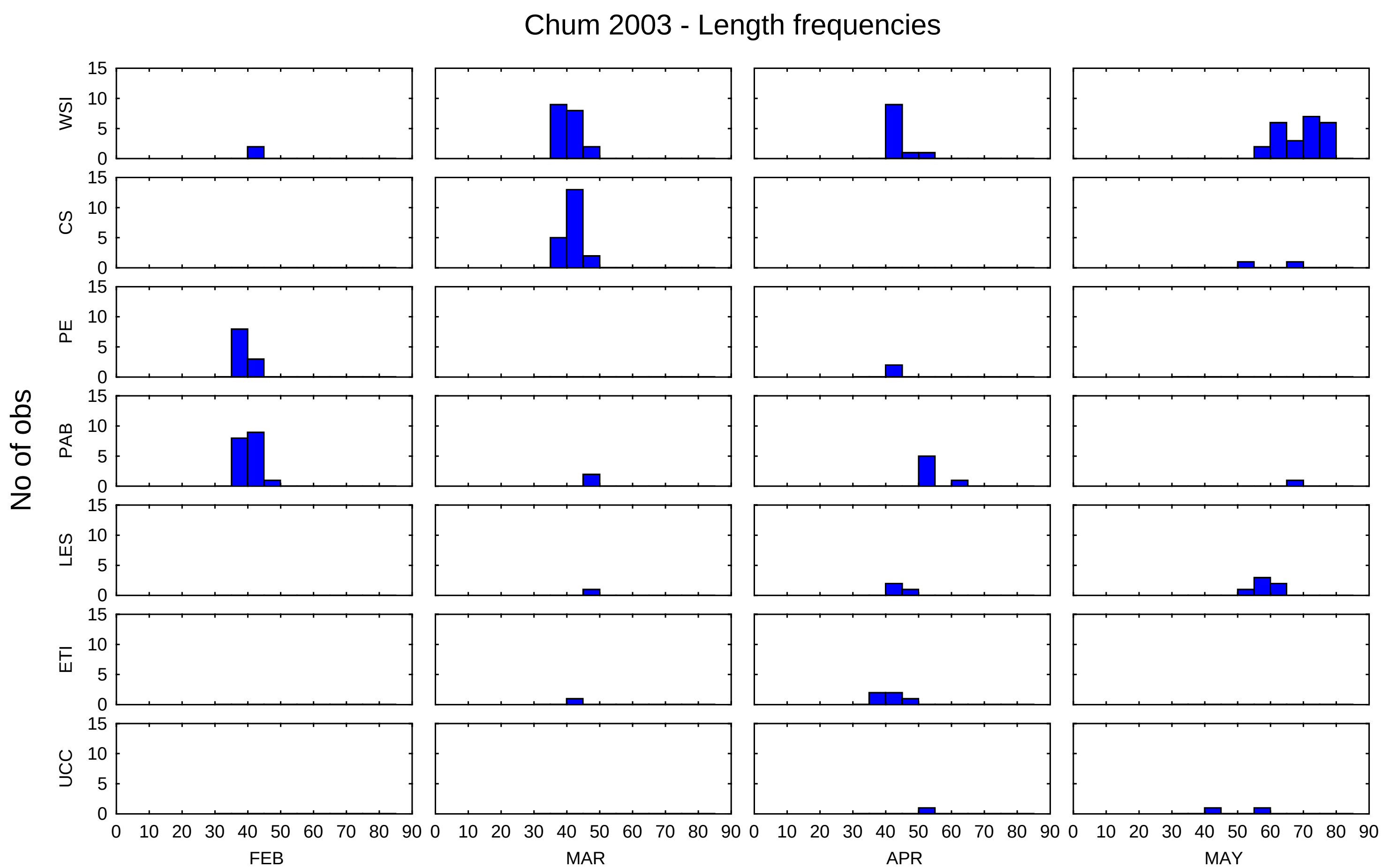

Figure 5. Monthly size frequency histograms of chum salmon sampled with beach seines at lower estuarine (CS, USS), upper estuarine (PAB, PE), and freshwater stations (UCC, LES, ETI) during 2002. Only months when chum salmon were observed are shown.

1.3. Characterize physical factors.

The physical variables that control and affect the availability of habitat in the lower river and estuary, such as salinity, temperature, and turbidity are being monitored. This task overlaps with and is detailed in Task 2.3 below.

1.4 Characterize juvenile life history characteristics and habitat associations using scales and otoliths

We processed 667 chinook salmon retained from 2002 and 2003 beach seine samples for detailed analysis of genetics, otoliths, and scales. An additional 653 fin clip and scale samples were collected from released chinook. These samples are presently being analyzed for life history characteristics and habitat associations.

In order to more fully understand how juvenile chinook salmon utilize estuary habitat in the lower Columbia River, and potential effects on growth and survival, there are four specific and crucial data needs: 1) when do fish enter what we characterize as estuary habitat, 2) at what size do they enter, 3) how long have they resided in the estuary prior to capture, and 4) what are their growth rates while living in the estuary? Each of these parameters, viewed individually and as an integrated whole, provides the most basic understanding of how estuary habitat is tied to chinook salmon life history and ultimately, how it may influence overall survival. Unfortunately, obtaining these data by traditional mark-recapture or survey methods is daunting for a variety of practical and economic considerations. While survey data through time is valuable for understanding estuary use from a general population perspective, data on individual life histories prior to capture is not available. It is possible to obtain individual fish data from mark and recapture studies, however, it is extremely difficult and expensive to envision such an effort on the scale of the Columbia River. Furthermore, there is always a question as to the behavioral and growth effects of the marking procedure. Externally applied batch color marks may fade or disappear over time, and internal tags (PIT tags) cannot be used to characterize the life histories of very small subyearling salmon (e.g., < 55 mm).

Our approach to these problems is to use otolith chemical and structural analyses as a means to acquire each of the four critical data needs for any individual fish captured. We have demonstrated the practicality of this approach in a similar project on the Salmon River, Oregon (manuscript in preparation). A brief description of how the data is acquired will show the utility of these analyses. Once the otolith has been sectioned to reveal the entire life history of the individual, from initial otolith formation in the embryo to death, a chemical analysis transect is performed across the otolith using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). This results in a detailed profile of strontium abundance in the otolith (Figure 6). Since strontium to calcium (Sr/Ca) ratios typically increase in proportion to habitat salinity, these values are a useful indicator of when fish encounter estuary habitat. A number of papers have demonstrated the environmental connection between habitat salinity and otolith Sr/Ca values. Thus, we can partition Figure 6 into otolith regions that correspond with specific life history or habitat associations of the migrating juvenile chinook salmon. The sudden and dramatic increase in strontium abundance (shaded box) hallmarks estuary entry for this individual, following a long period of low strontium count rates

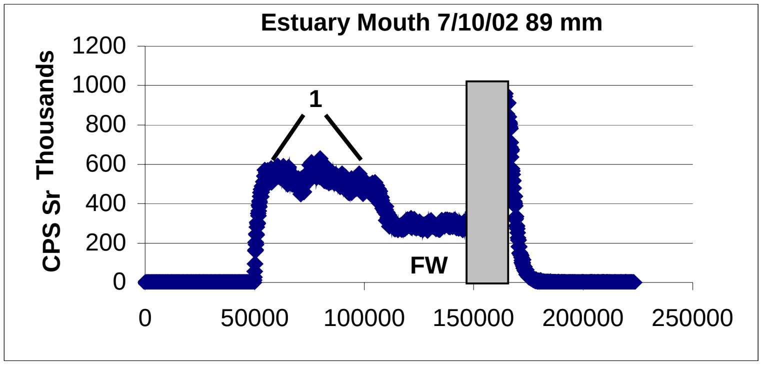

Figure 6. Plot of strontium abundance across otolith transect from a Salmon River, OR chinook salmon.

corresponding to freshwater residence (FW). Region 1 represents elevated strontium count rates in the otolith core during the embryo and alevin stage resulting from maternal anadromy. Once the point of estuary entry is identified on the otolith, the close relationship between fish size and otolith size (typical rsq. > 0.90) can be used to estimate the size at which fish entered the estuary. Additionally, we can locate the estuary entry point on the otolith section and count otolith increments, produced daily, to gain an estimate of estuary residence time to capture. Finally, since we have an estimate of size at entry and a known size at capture, with a measure of time between estuary entry and death, we can estimate growth rates for each individual fish over the period of estuary residence. Also, assuming most fish emerge from the gravel at approximately the same size, we are able to obtain a relative measure of residence time in fresh water habitats. These data components represent a fairly complete description of life history for every individual of interest and allow us to paint a detailed picture of relationships between estuary habitat and juvenile chinook life history.

Although we have only begun our analyses of otoliths from chinook salmon captured in the Columbia River estuary, results thus far are encouraging. The main point of these early analyses was to show that the pivotal chemical transition we depend upon, rising Sr/Ca values in otoliths from fish that have migrated into the estuary, were indeed present. Figure 7 shows the otolith strontium profile for a fish captured in Upper Cliffton Channel, and demonstrates the presence of the dramatic rise in strontium count rates we have come to expect with estuary entry. This is a strong indicator that the kinds of data we have been able to collect on other systems will also be achievable on the Columbia River. Ultimately, this sort of data can also be collected from otoliths of returning adults, allowing us to examine connections between life history and survival.

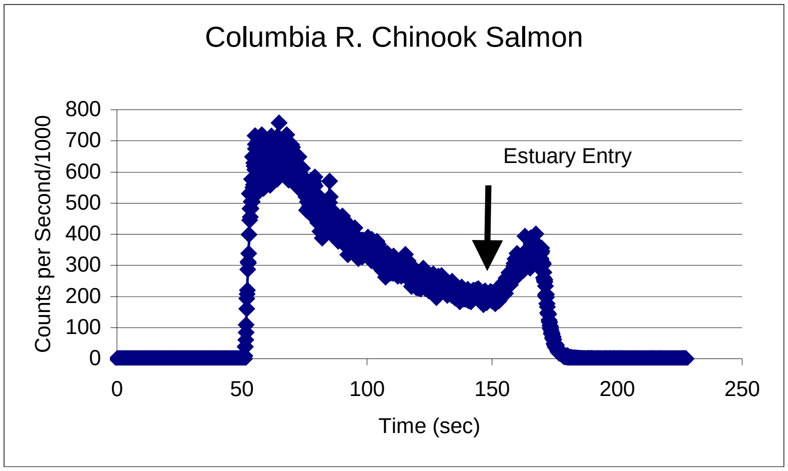

Figure 7. Otolith strontium profile from a juvenile chinook salmon collected from Upper Clifton Channel.

<u>1.5 Time series of juvenile salmon abundance</u>

No activity in 2003

<u>1.6 Monitor trophic relationships of salmonid species and life history types in selected habitats throughout the lower Columbia River estuary.</u>

Stomach contents of chinook salmon collected during beach seining are being analyzed to assess habitat utilization and tropic linkages. Data include: (1) stomach fullness rank, (2) the weight of stomach contents, and (3) diet composition (e.g. terrestrial insects, benthic invertebrates, plankton, fish). These data will be used to determine the extent salmon are feeding throughout the sample range, the prey types consumed, and whether salmon diets exhibit any significant seasonal or spatial variation within the lower river and estuary.

To date, forty stomach samples collected in May 2002 and May 2003 from four sites (West Sand Island and Clatsop Spit in the estuarine zone, and Lower Elochoman Slough and Upper Clifton Channel in the freshwater zone) have been processed. The data suggest subyearling chinook are feeding in both marine-dominated and freshwater areas, as only one fish examined had an empty stomach and half of the fish examined had stomachs more than 50% full (Table 10). Prey composition of identifiable material was dominated by the benthic amphipod *Corophium* sps. throughout the sampled range. However, terrestrial insects were common prey in the freshwater habitat, whereas marine fish and crab larvae were more common prey in the marine-influenced habitat (Table 11).

Table 10. Frequency of fullness rankings for stomachs of forty juvenile chinook salmon captured in May of 2002 and 2003.

Stomach volume fullness ranking	**Number of stomachs**
Empty	1
< 25% full	14
26% to 50% full	5
50% to 75% full	6
100% full	10
100% full and distended	4

Table 11. Frequency of occurrence of prey types found in stomachs of forty juvenile chinook salmon captured in May of 2002 and 2003.

Lower estuary		**Freshwater**	
Prey type	**%**	**Prey type**	**%**
Corophium salmonis	25	*Corophium salmonis*	75
Fish larvae	20	Dipterans	40
Corophium spp.	15	*Corophium* spp.	20
Corophium spinicorne	15	Coleoptera (beetles)	15
Cumaceans	15	Dipteran larvae	10
Dipterans	10	Mysid shrimps	10
Crab larvae	10	*Corophium spinicorne*	5

Objective 2. Describe salmonid use and performance in selected emergent and forested wetlands and their relationship to local habitat features.

2.1 Sample fish at emergent and forested wetland sites in Cathlamet Bay

We used trapnets to sample juvenile salmonids and other fish species in three areas of Cathlamet Bay (Figure 1). Two of the sampling areas are intertidal emergent marshes, one on Russian Island (RI) and the other on Seal Island (SI). Each area was sampled at two replicate tidal channels (north and south). The third sample area is Karlson Island, where two types of tidal channels are represented, forested and shrub. The forested site (KIF) has large woody debris and mature conifers along the banks, whereas the shrub site (KIS) has lesser amounts of small woody debris and is lined with deciduous bushes and shrubs.

The trapnets consist of two wing nets (0.75-in mesh) connected to a tunnel that leads to a live box (0.25-in mesh). The tunnel and live box are placed in the channel thalweg, and the two wing nets are set to opposite channel banks. The wing nets direct outmigrating fish into the live box. The trapnet is set at high tide, and when the tide recedes all fishes that entered the marsh channel during the flood period are captured. Fish samples were treated as described above for beach seines. We sampled fish monthly from March through August at Russian Island, and April through August at Seal and Karlson Islands.

In 2003, among all three sample areas combined, we captured 14 fish species totaling 173,172 individuals (Tables 12-14). At all sites, threespine stickleback was by far the dominant species throughout the year. Sticklebacks accounted for 99% of the Russian and Seal Island total catch, and 86% of the shrub-channel and 68% of the forested-channel catch at Karlson Island. Other commonly represented species in the 2003 catches were prickly sculpin, peamouth (*Myocheilus caurinus*), large scale sucker (*Catostomus macrocheilus*), and chinook salmon.

Table 12. Abundance of species sampled by trapnet at Russian Island during 2003. N, North site; S, South site.

Species	March		April		May		June		July		August		
(common name)	N	S	N	S	N	S	N	S	N	S	N	S	Total
American shad				1		1		1			1		4
Banded killifish		2	3	1	1	4	5	11			5	18	50
Black Crappie							1						1
Chinook salmon - subyearling	5	16	5	142	42	156		6	3	1			376
Chinook salmon - yearling		1				1							2
Chum salmon		1	3	22	4	2							32
Coho salmon		1		5									6
Peamouth		1		2	14	47	45	196	1	26			332
Prickly Sculpin			1										1
Staghorn Sculpin				3									3
Threespine stickleback	4655	3517	73	9164	18119	21652	15587	23840	5179	6319	263	1931	110299
Total	4660	3539	85	9340	18180	21863	15638	24054	5183	6346	269	1949	111106

Table 13. Abundance of species sampled by trapnet at Seal Island during 2003. N, North site; S, South site.

Species	March		April		May		June		July		August		
(common name)	N	S	N	S	N	S	N	S	N	S	N	S	Total
American Shad					2						1		3
Banded killifish			11	3	78	4	1	2	4		19	3	125
Chinook salmon - subyearling			52	19	153	108	23	2	2		1		360
Chinook salmon - yearling			1			1							2
Chum salmon			14	3	6								23
Largemouth Bass												1	1
Peamouth			3	1	32	10	15		4				65
Prickly sculpin					1								1
Threespine stickleback			6606	2824	16678	14214	9053	1973	1709	169	543	248	54017
Total	nd		6687	2850	16948	14337	9092	1977	1719	169	563	252	54594

Table 14. Abundance of species sampled by trapnet at Karlson Island during 2003. F, Forested site; Sh, Shrub site. *channel did not drain sufficiently to collect any fishes.

Species	March		April		May		June		July		August		
(common name)	F	Sh	F	Sh*	F	Sh	F	Sh	F	Sh	F	Sh	Total
American shad								1			352	437	790
Banded killifish										1		3	4
Chinook salmon -subyearling			35		15	32	5	6	1	3		2	99
Chum salmon						1							1
Coho salmon					3		2	3					8
Largemouth bass									3				3
Largescale sucker										2	2	63	67
Peamouth					3	21	11	4	1	4	5	16	65
Prickly sculpin			1			30		34		57	10	76	208
Starry flounder								1					1
Threespine stickleback			78		253	1923	533	2031	55	784	40	490	6187
Unidentified sculpin			1		1	5		13	3	4		12	39
Total	nd		115	0	275	2012	551	2093	63	855	409	1099	7472

Results to date indicate that juvenile salmon rear in shallow marsh habitats of the Columbia River during spring and summer months. Salmonid species composition in the marshes varied monthly; chum and coho salmon appeared in all areas during the spring (March-May), and chinook salmon were present throughout the sampling season but peaked in April or May. In 2003, chinook salmon catches rapidly declined by June, likely due to warmer water conditions. Although the catch totals in Tables 12-14 accurately depict species composition and relative abundances at each site, between-channel comparisons of fish abundance are not yet possible since the channel areas and volumes sampled above each trapnet are not identical. During 2004, we will use aerial imagery, remote sensing, and other available resources to estimate channel areas and volumes and to standardize fish counts at each trap site.

Preliminary length-frequency analyses for chinook salmon show that marsh habitats are utilized primarily by subyearling migrants (Figure 8). Temporal patterns of chinook salmon size varied amongst areas. Mean fork lengths generally increased with time at Russian Island- North and both Karlson Island sites, while mean fork lengths remained relatively constant at the other sites. Forthcoming scale and otolith analyses will provide additional details about the life histories and growth of juvenile salmon inside and outside of shallow marsh habitats.

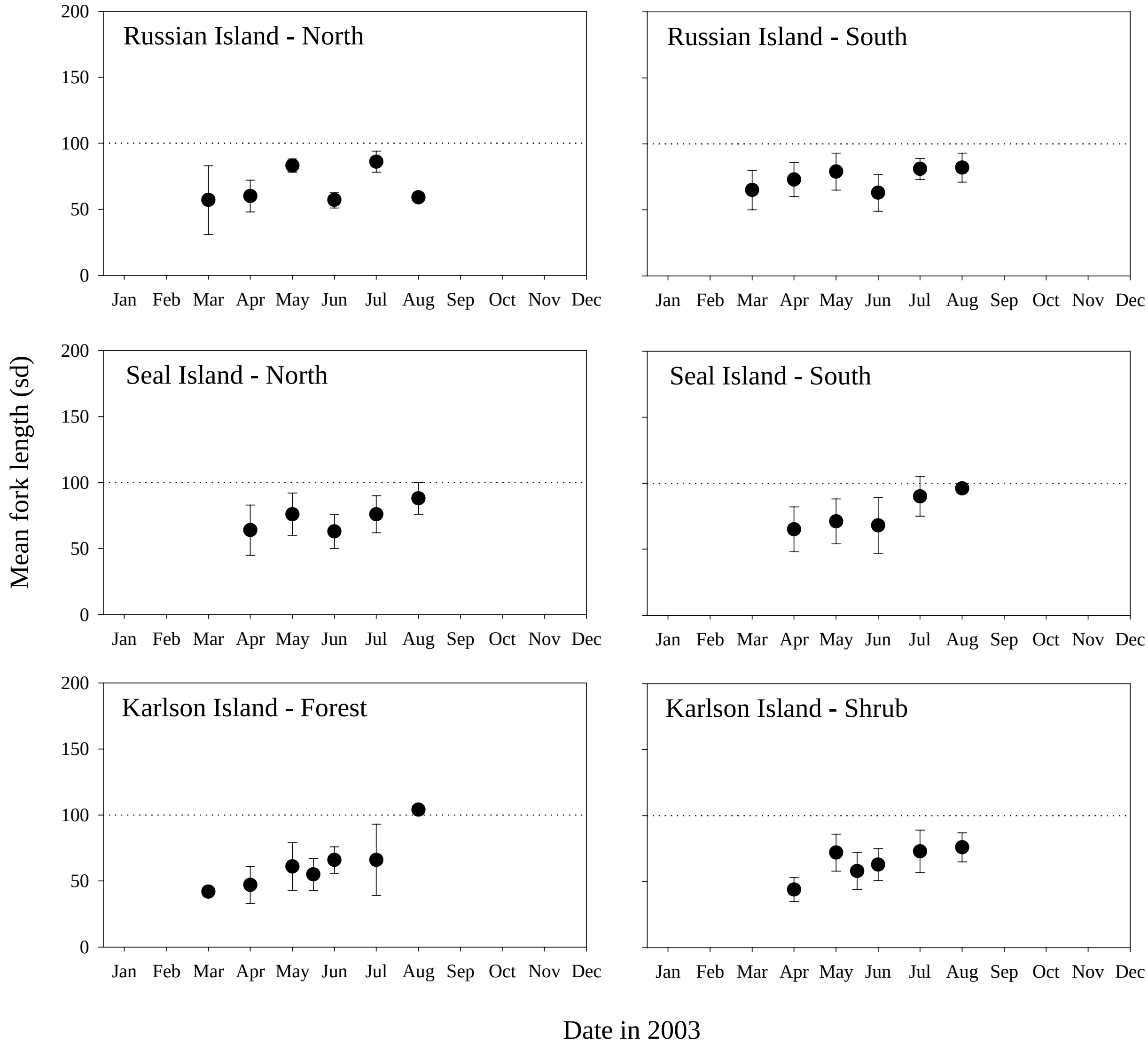

Figure 8. Time series of mean fork length (± SD) of chinook salmon sampled by trapnet at six freshwater stations during 2003. Dashed line at 100 mm is for comparative purposes.

2.2 Monitor availability of invertebrate prey resources and food habits of juvenile salmonids and other selected fish predators

During 2002 and 2003, we examined utilization of prey resources by juvenile salmon collected from emergent marsh, and forested, and scrub-shrub wetland habitats in Cathlamet Bay. Prey resource utilization was determined by (1) analysis of salmon stomach contents, including the diet composition, fullness, and instantaneous consumption rate, and (2) the density and taxa composition of available prey. The tidal channel trapnet samples described above were used to obtain samples of juvenile salmon for diet analyses. Insect fallout traps (IFT) and benthic cores were used to sample potentially available insect and benthic invertebrate prey, respectively.

Insect fallout traps were used to estimate the quantity and composition of insects falling onto the surface waters of adjacent tidal channels as an indication of prey potentially available for juvenile salmon occupying the channels. The IFT consist of a plastic bin (51.7 cm x 35.8 cm x 14 cm) half filled with soapy water. The bin rests on a platform of PVC pipe that is inserted into the marsh substrate. It is then surrounded with three poles that prevent the trap from floating away, while allowing it to rise and fall with the tides. Five IFT were placed along the margin of each study channel within 100 meters of the mouth of the channel. All the traps were set on the same day and collected after 48 hours. Insects were identified to the lowest taxonomic level feasible under a dissecting microscope.

At each of the IFT positions along the margin of a tidal channel, a PVC benthic core (19.6 cm^2 area) was inserted 10 cm into the channel substrate to sample macroinvertebrate fauna. Samples were collected along the tidal channel gradient at low tide. Organisms were identified to the lowest taxonomic level feasible under a dissecting microscope.Thirty IFT traps and 30 benthic cores were collected each month from March to August 2002 and April to August 2003.

Table 15. Number of prey availability samples collected from forested and scrub-shrub wetland at Karlson Island (KI-F and Ki-Sh, respectively) and north and south channels of emergent marsh in Russian Island (Rul-N and Rul-S, respectively) and Seal Island (SI-N and SI-S, respectively).

2002	**KI - F**	**KI - Sh**	**RuI - N**	**RuI - S**	**SI - N**	**SI - S**	**Total**
March	7		2	4			13
April	6	10	10	11	15	11	63
May	21	28	11	10	11	10	91
June	10	11	7	26	10	10	74
July	2	6	11	10	11	8	48
August	1	2	1	10	3	1	18
Total	47	57	42	71	50	40	**307**

2003	**KI - F**	**KI - Sh**	**RuI - N**	**RuI - S**	**SI - N**	**SI - S**	**Total**
April	12		4	22	20	16	74
May	11	11	20	20	14	17	93
June	5	6		6	16	2	35
July	1	3	3	1	2		10
August		2					2
Total	29	22	27	49	52	35	**214**

Preliminary analysis of juvenile salmon diet samples from April and May 2002 (n=85), and April and May 2003 (n=181) indicate that emergent insects (primarily from order Diptera; family Chironomidae and Psychodidae) and benthic amphipods (*Corophium* spp.) dominated the diet of juvenile chinook (Figure 9). Although this diet composition was somewhat representative of all sites, variations among specific habitats and size classes are apparent (Figure 10). For example, smaller fish < 60 mm fed primarily on chironomids (a small, terrestrial dipteran insect), whereas prey taxa were more diverse in chinook > 60 mm in size.

To date, we have analyzed and processed prey availability observations derived from IFT catches during April and May 2002. Insect trap composition is dominated by terrestrial dipteran insects, primarily chirnomomids. In April, Psychodidae (order Diptera) and Sialidae (order

Neuroptera) were also prevalent in the traps. IFT samples from the four emergent marsh sites contained much higher numbers of insects when compared to the two Karlson Island forested and scrub-shrub sites (e.g, Figure 11). The differences in vegetation community between the emergent marsh sites and the forested/scrub-shrub sites could account for some of the numerical differences we see in insects between the sites.

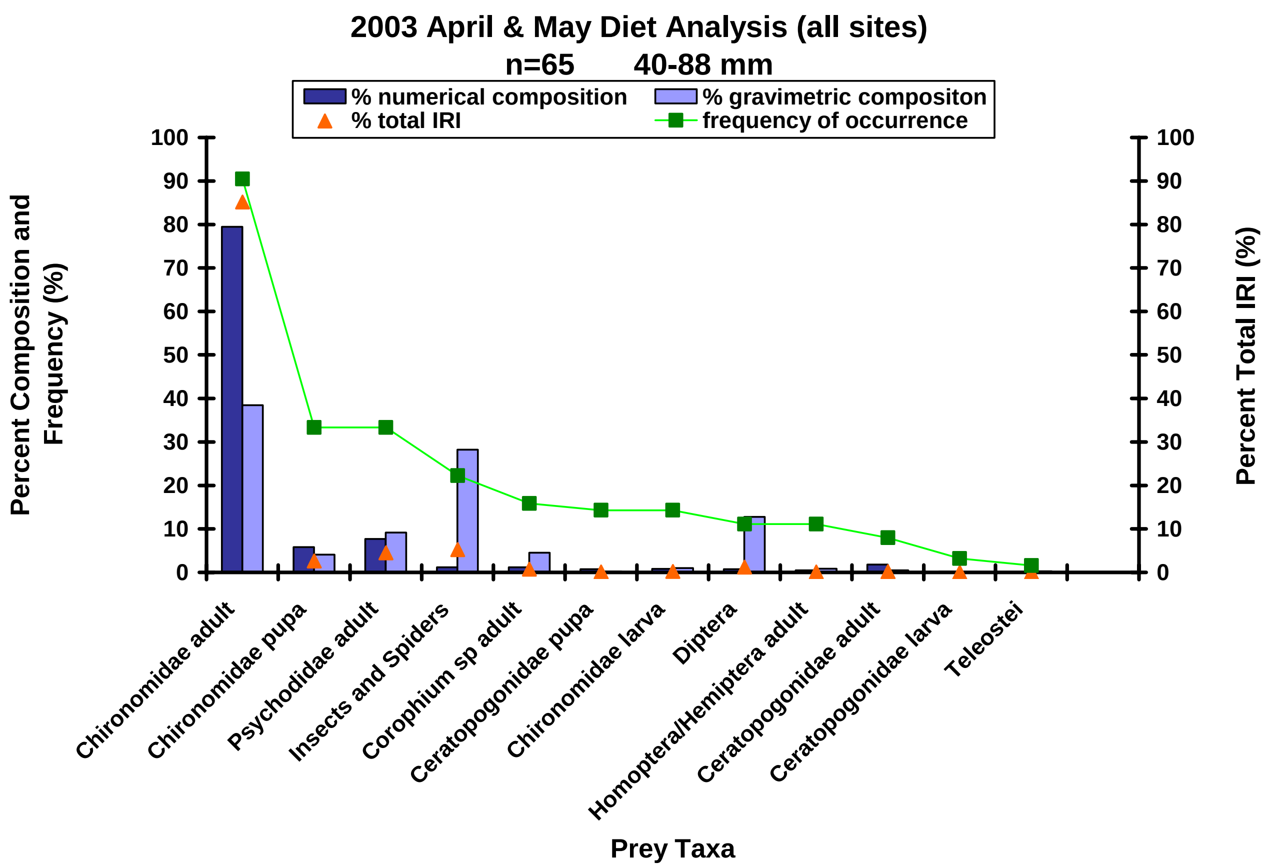

Figure 9. Composite diet of juvenile chinook salmon in Cathlamet Bay wetland tidal channels, April and May 2003.

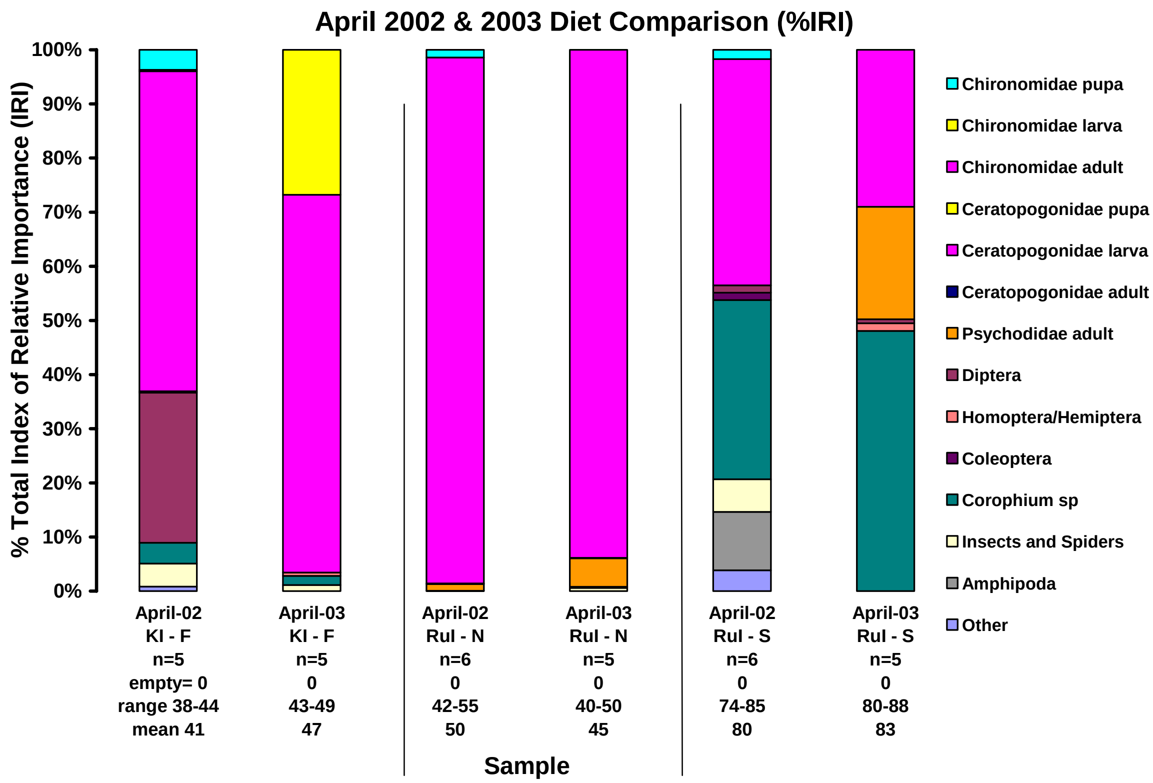

Figure 10. Diet composition (%Total IRI) of juvenile chinook salmon at different Cathlamet Bay wetland tidal channels, April 2002 and 2003. KI-F: Karlson Island Forested; RuI-N: Russian Island North; RuI-S: Russian Island South.

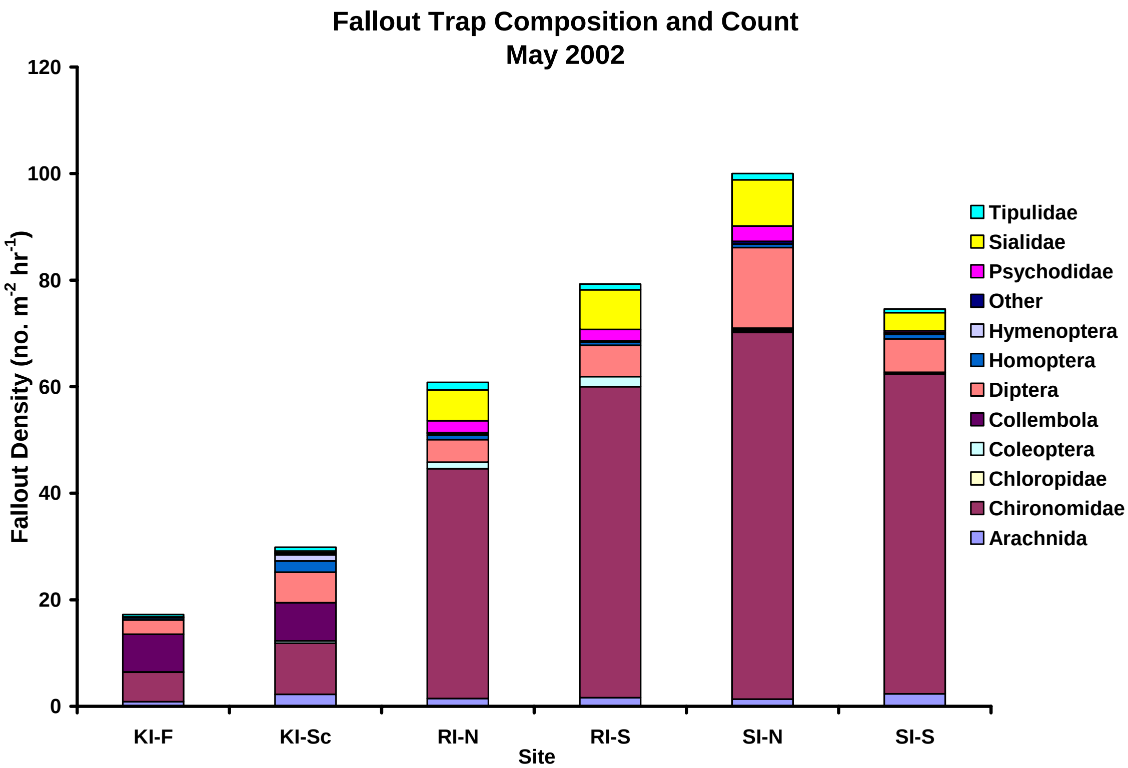

Figure 11. Density of potential juvenile salmon prey in insect fallout traps (IFT) at different Cathlamet Bay wetland tidal channels, May 2002. KI-F: Karlson Island Forested; Kl-S: Karlson Island Scrub-Shrub; Rul-N: Russian Island North; Rul-S: Russian Island South; SI-N: Seal Island North; SI-S: Seal Island South.

We have also processed and analyzed the data from benthic core samples from April and May 2002. The composition of potential invertebrate prey sampled with the benthic core varied both spatially and temporally. In April, other than the numerically prominent oligochaetes and nematodes, chironomid and ceratopogonid insect larvae (small dipteran emergent insects) dominated at most sites, with polychaete annelids (*Manayunkia* spp.) and ostracods occurring secondarily (Figure 11). Densities were comparable at Russian Island-South, both Seal Island sites, and Karlson Island-Forested, but were considerably lower at Russian Island-North and Karlson Island-Shrub. In May, potentially available macroinvertebrate prey (excluding oligochaetes and nematodes) at all sites were considerably more abundant than the previous month except at Russian Island-South channel (Figure 12). In addition to chironomid and ceratopogonid larvae and ostracods, amphipods, gastropods, and bivalves were more abundant in May than in April.

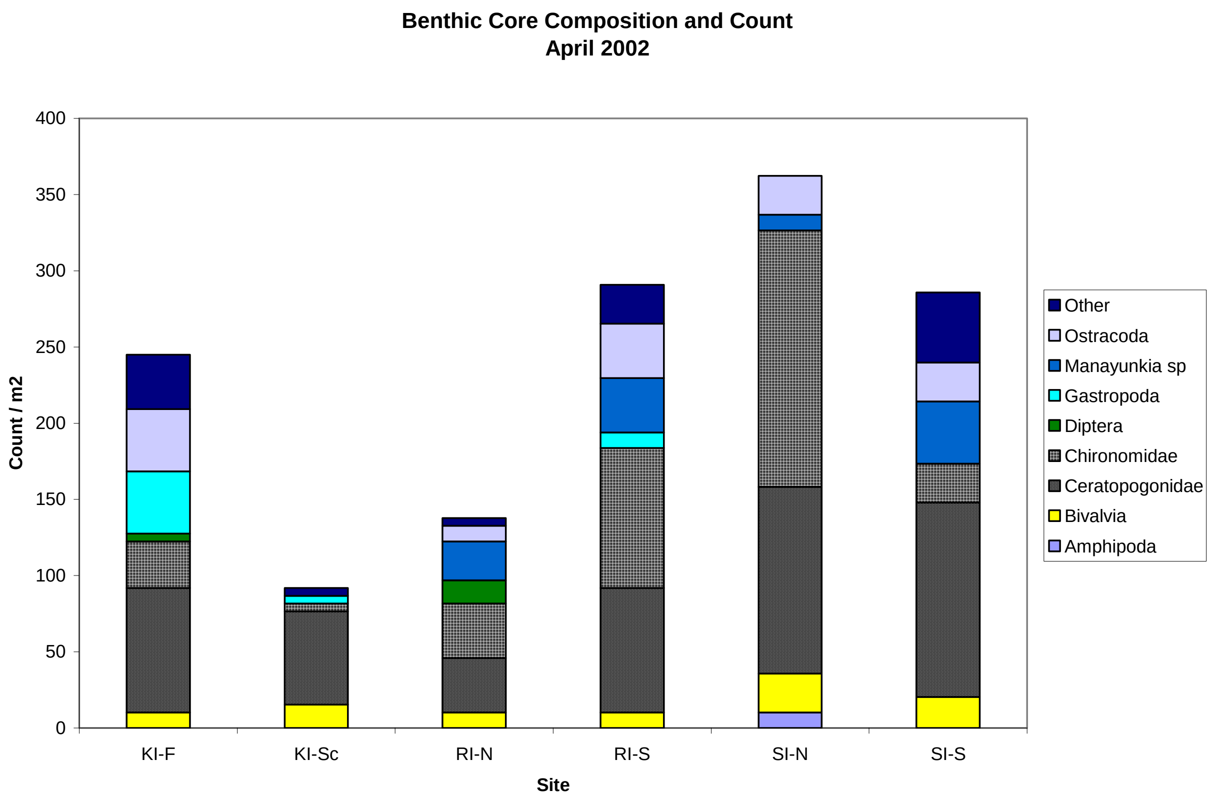

Figure 12. Relative density of benthic macroinvertebrates (excluding oligochaetes and nematodes) in benthic cores at different sites Cathlamet Bay wetland tidal channels, April 2002. KI-F: Karlson Island Forested; Kl-S: Karlson Island Scrub-Shrub; Rul-N: Russian Island North; Rul-S: Russian Island South; SI-N: Seal Island North; SI-S: Seal Island South.

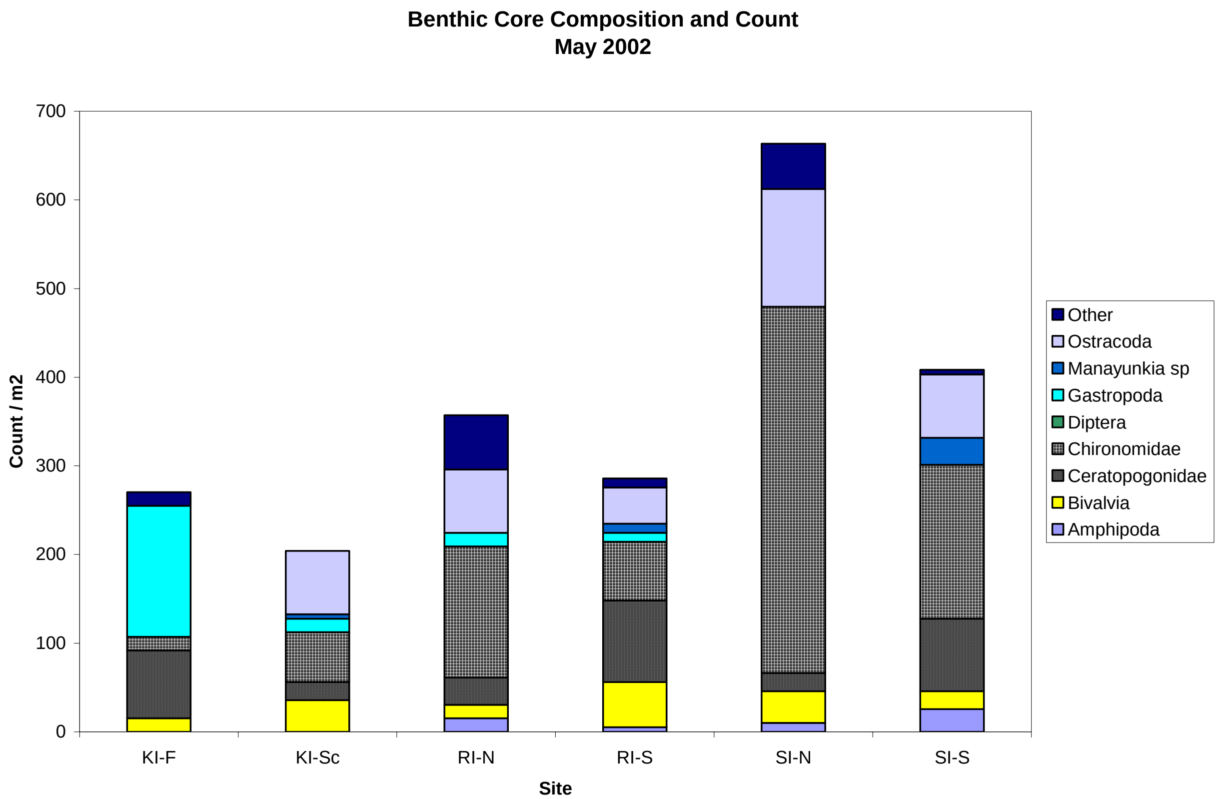

Figure 13. Relative density of benthic macroinvertebrates (excluding oligochaetes and nematodes) in benthic cores at different sites Cathlamet Bay wetland tidal channels, May 2002. KI-F: Karlson Island Forested; Kl-S: Karlson Island Scrub-Shrub; Rul-N: Russian Island North; Rul-S: Russian Island South; SI-N: Seal Island North; SI-S: Seal Island South.

2.3 Characterize physical factors

Throughout the study region, we are monitoring physical attributes including temperature, salinity, tide level, and other features. The characterization and interpretation of physical factors includes: (1) monitoring the physical attributes via the CORIE network, (2) monitoring the physical attributes of beach seine sites and of channels located within selected marsh habitats, (3) estimation of physically-based habitat opportunity indicators, and (4) interpretation of observed change (2003 and beyond). The results to date are discussed below.

2.3a Monitor physical attributes

We continued to maintain observation stations in Cathlamet Bay as an integral part of the CORIE network of real-time physical observations in the lower Columbia River and estuary (Figure 14). The in-water sensors of the Cathlamet network are outlined in Table 16. Additionally, atmospheric sensors are installed in the Marsh Island station including a wind speed and direction probe, and an air temperature and relative humidity probe housed in a radiation shield. Data are collected at 0.5 Hz, and then locally processed to describe at 10-minute intervals wind speed and direction, peak gust, air temperature, and relative humidity. More experimentally, solar radiation is measured with a Yankee Environmental Systems Total Solar Pyranometer for wavelengths between 0.3 μm and 3 μm, and an Eppley Laboratories Precision Infrared Pyranometer, from 3.5 μm to 50 μm; for both sensor models, we are using two instruments, one facing upward and the other downward.

Table 16. CORIE stations supported by this project.

Station	Instrumentation	Telemetry	Starting Date
MOTTB	Conductivity, Temperature Pressure (CTD)	Radio	2000
CBNC3	CT	Radio	2000
SVEN1	CTD	Radio	2001
MARSH	CTD	Radio	2001
	Atmospheric station (see text)	Radio	Experimental
ELIOT	CTD	Radio	2001
TNSLH	TD	Radio	2003

The CORIE web site reports most of the data from in-water sensors on a real-time basis which can be accessed at http://www.ccalmr.ogi.edu/CORIE/network. Observed salinity (via conductivity), temperature, and pressure data are publicly available. For each station, users can visualize and download quality-controlled data. For example, data from the Mottb sensor can be viewed at http://www.ccalmr.ogi.edu/CORIE/data/publicarch/mottb (see also Figure 15). Other products include statistical compilation of physical datasets (climatology), for example: http://www.ccalmr.ogi.edu/CORIE/data/publicarch/mottb/clim.html. Users can access one-year ensemble views of the physical datasets from the Cathlamet Bay sensor network at http://www.ccalmr.ogi.edu/CORIE/data/publicarch/ensemble/. The CORIE web site also contains a description of the adopted quality control procedures which have become CORIE standards at http://www.ccalmr.ogi.edu/CORIE/data/publicarch/methods_quality.html.

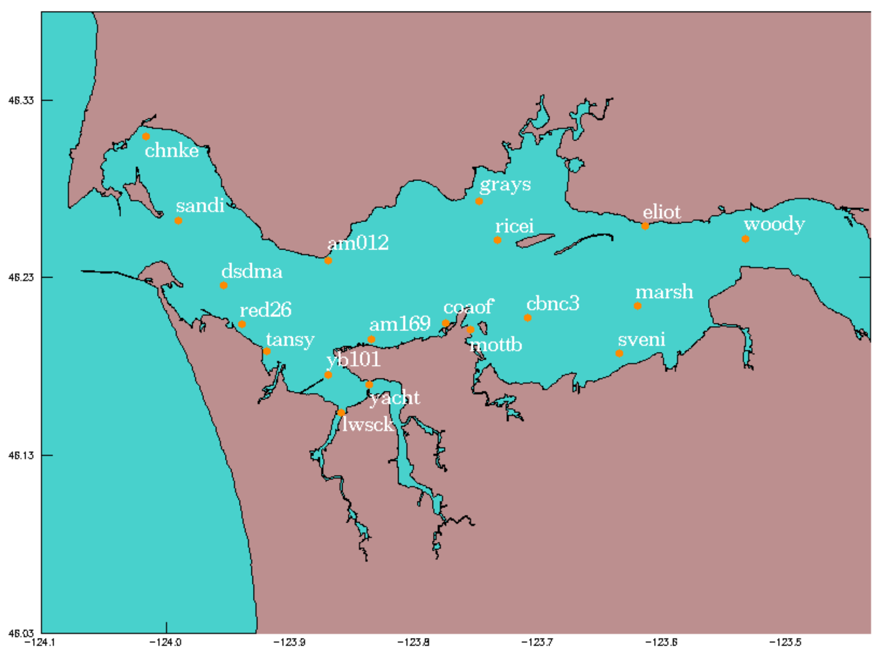

Figure 14. Mooring stations comprising the CORIE Network.

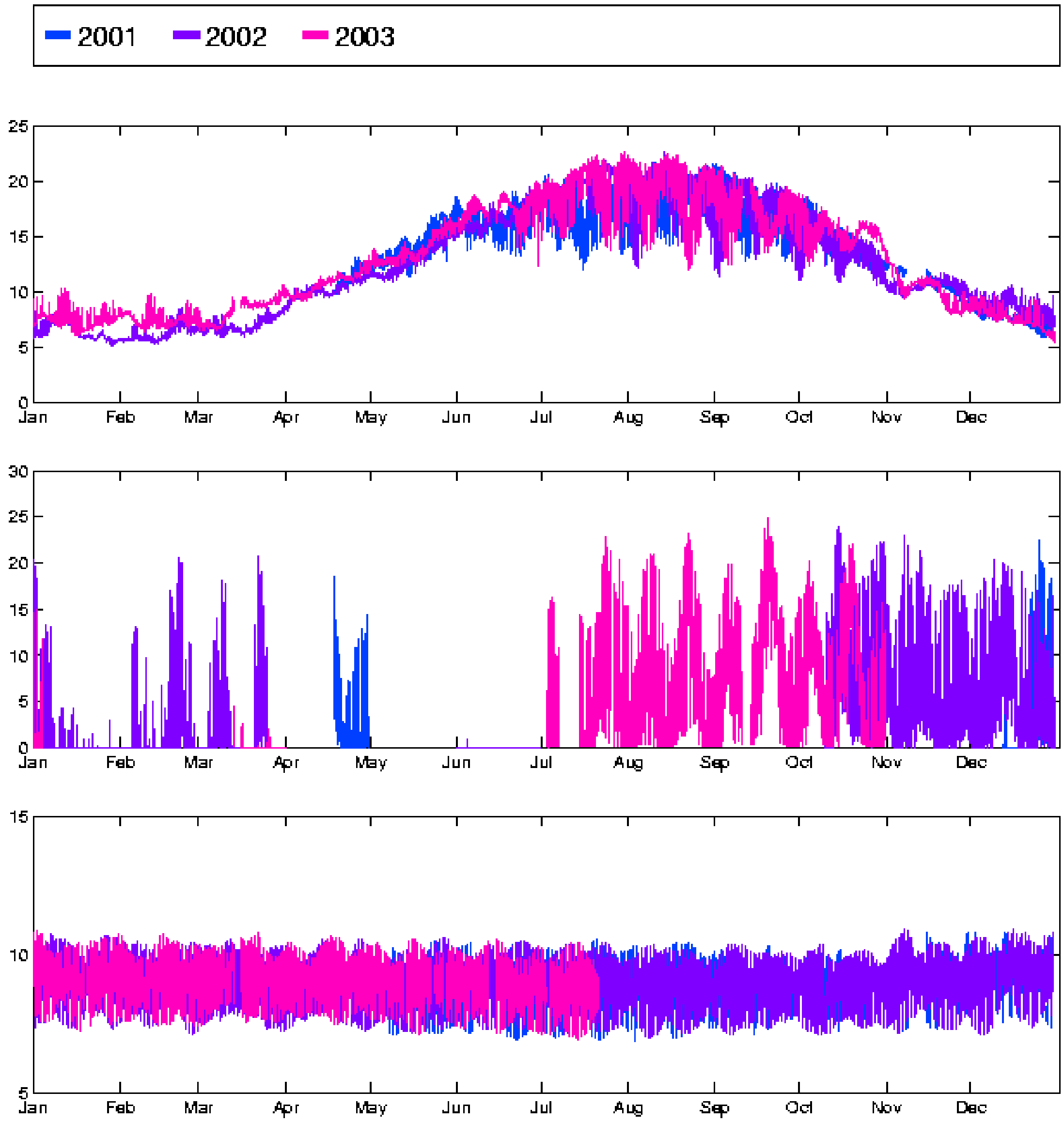

Figure 15. Temperature (°C), salinity (psu) and pressure (m) records at Mott Basin (2001-2003).

2.3b Characterize physical factors during beach seining and monitor physical attributes within selected marsh habitats

During regular beach seine operations, we profiled the water column with a Sea Bird 19 plus CTD equipped with a Turner Designs SCUFA optical backscatterance sensor and a Wet Labs Wet Star fluorometer. Four casts were made perpendicular to shore in a transect extending from the beach seine site (2-5 m depth) out to the channel 250-300 m from shore. These data are used to evaluate vertical and horizontal gradients of salinity, temperature, chlorophyll a, and turbidity that may influence fish abundance. Data have been collected from November 2002 to the present.

To date, we have observed large variation in patterns of physical gradients among sites and sample periods. Variability over spatial (stations WSI, PE and LES) and seasonal (February, May, July and October 2003) scales are presented in Figures 16-18 to illustrate these trends. Within a site, water masses were nearly isothermal with both horizontal and vertical temperature gradients generally < 1^{o}C. However, seasonal temperature variation was large (6 to 22^{o}C) and was mostly a function of river water temperature. Salinity patterns varied widely, depending on seasonal factors and time of the tide we sampled. Mixing of river and ocean water resulted in highly stratified conditions at the estuarine stations, and intense vertical salinity gradients, at times exceeding 1 psu m^{-1}, were observed at nearshore sites. At the surface, strong convergence zones could result in horizontal gradients exceeding 4 psu over a 250 m transect. Salt was not detected at the three upriver sites. Chlorophyll concentration exhibited marked seasonal fluctuations related to annual phytoplankton production, with maximum concentrations (>25 mg m^{-3}) found in river water during the spring bloom in April and May. However, vertical distributions of chlorophyll had surface minima and generally increased with depth. Turbidity patterns were quite variable, with strong vertical, horizontal, and between-site gradients apparent but without consistent pattern.

At the trapnet sites, temperature sensors were deployed at the Russian Island and Karlson Island-Forested site in May and at the Seal Island and Karlson Island-Shrub sites in June. The sensors are recording water temperatures at 10 minute intervals. The two emergent marsh sites displayed the greatest temperature variation, likely due to their exposure to the sun during the lowest summer tides (Figure 19). Water temperatures did not vary as dramatically at either of the Karlson Island sites. This probably reflects shading by dense overhead vegetation and ponding of water at low tide which ensures that the temperature sensors are always merged. At all sites, water temperatures began declining in mid-September and continued a cooling trend through December.

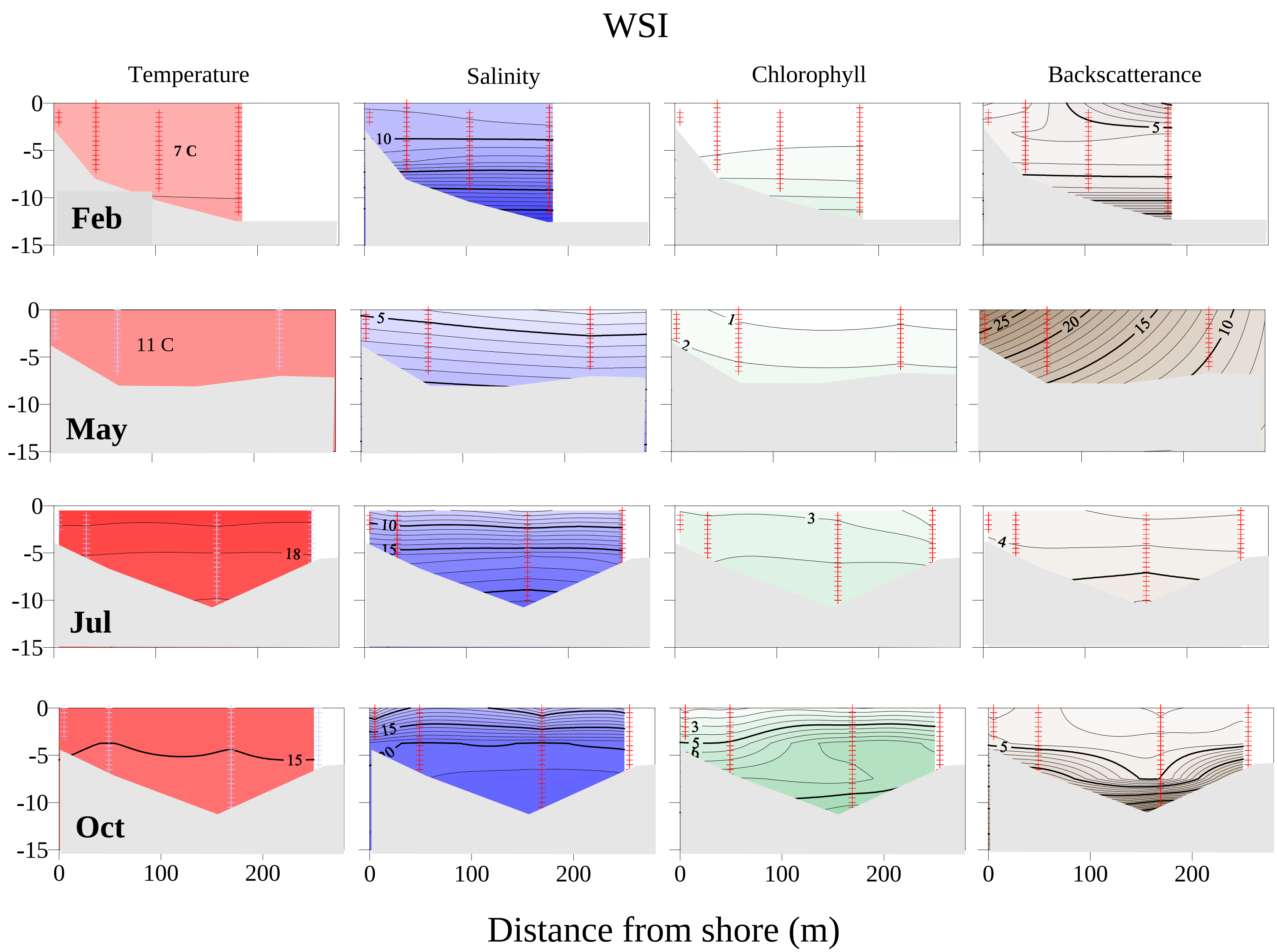

Figure 16. Seasonal patterns of temperature, salinity, chlorophyll, and turbidity at West Sand Island during 2003

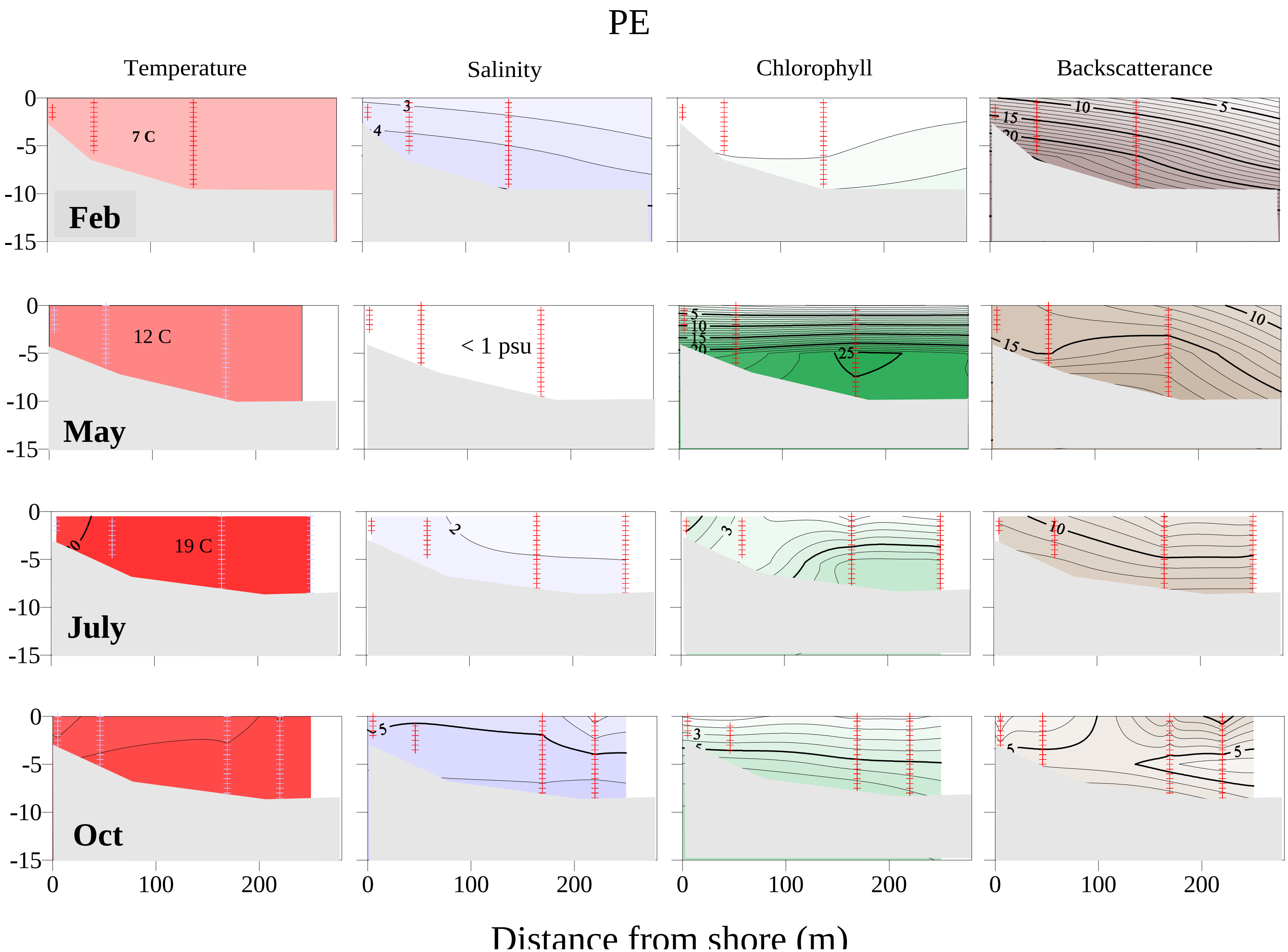

Figure 17. Seasonal patterns of temperature, salinity, chlorophyll, and turbidity at Pt. Ellice during 2003

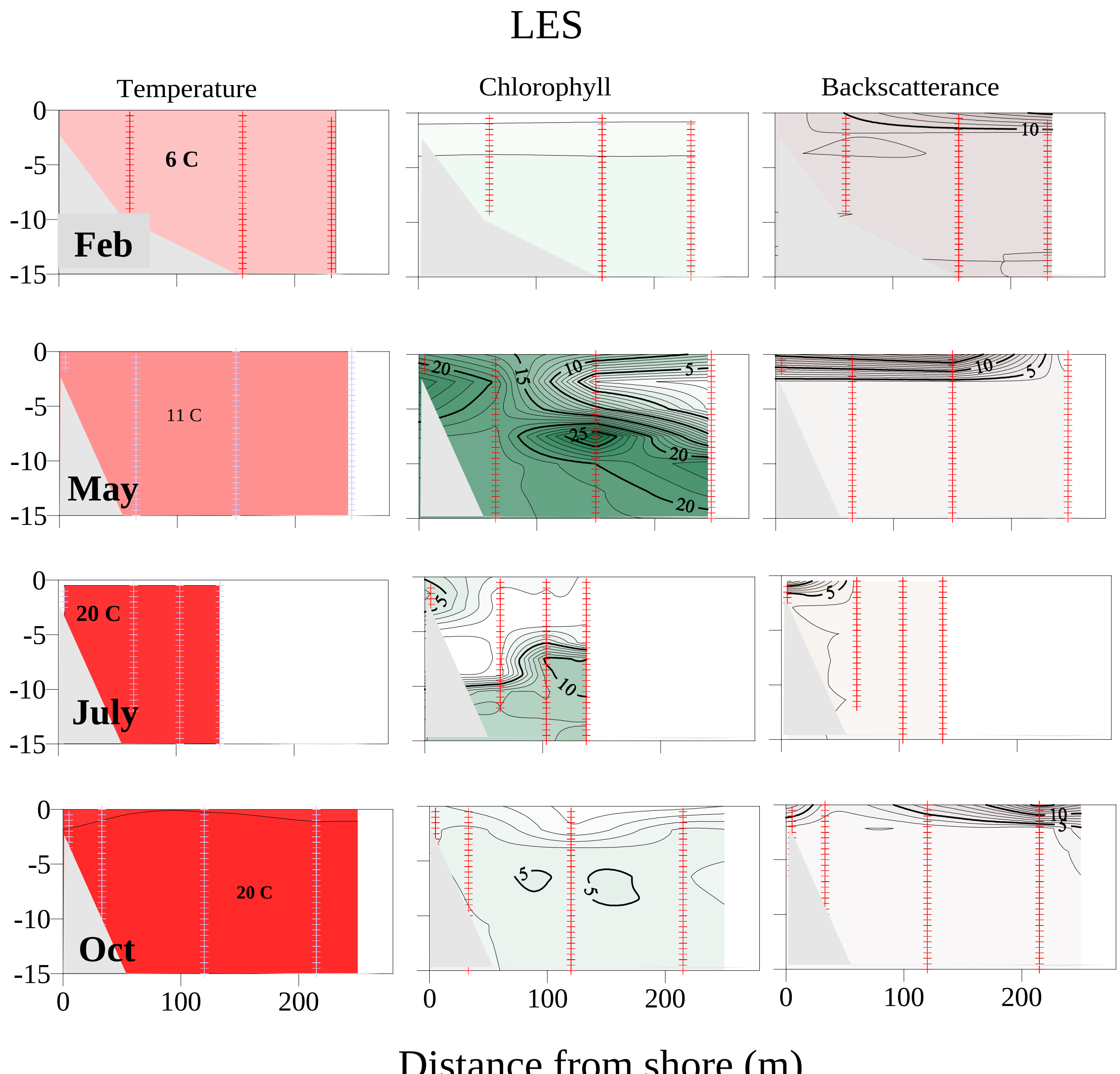

Figure 18. Seasonal patterns of temperature, chlorophyll, and turbidity at Lower Ellochoman Slough during 2003. Salinities did not exceed 0.5 psu.

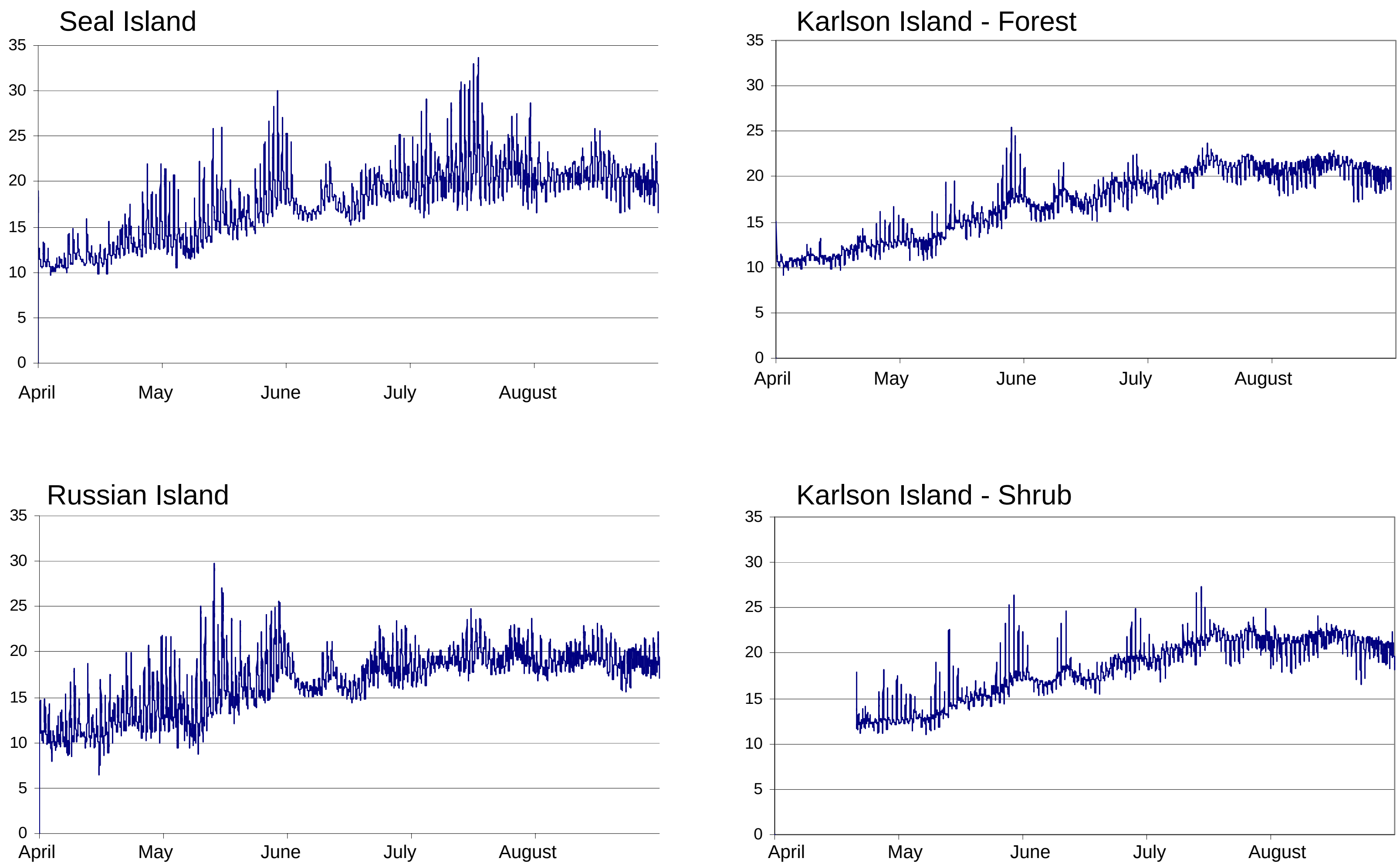

Figure 19. Time series of temperature at selected trapnet sites in Cathlamet Bay

2.3c Estimation of physically-based habitat opportunity indicators

Indicators of habitat opportunity for juvenile salmon based on water depth, velocity, and salinity have been developed as a way to evaluate the possible influence of spatial and temporal variability in the physical environment on the distribution and habitat use by salmon populations. To date, we have computed 2002 habitat opportunity metrics for the CORIE observation stations listed in Section 2.3a (based on salinity and velocity criteria; all stations are deep enough to make the depth criteria trivially zero at the station). We have also started producing maps with daily forecasts of habitat opportunity (depth, salinity and velocity criteria). An example is shown in Figure 20. We are developing the quality control procedures and display scripts necessary to support web-based access to that information. Results will be discussed in the next future principal investigator meetings, with routine web publication expected shortly thereafter.

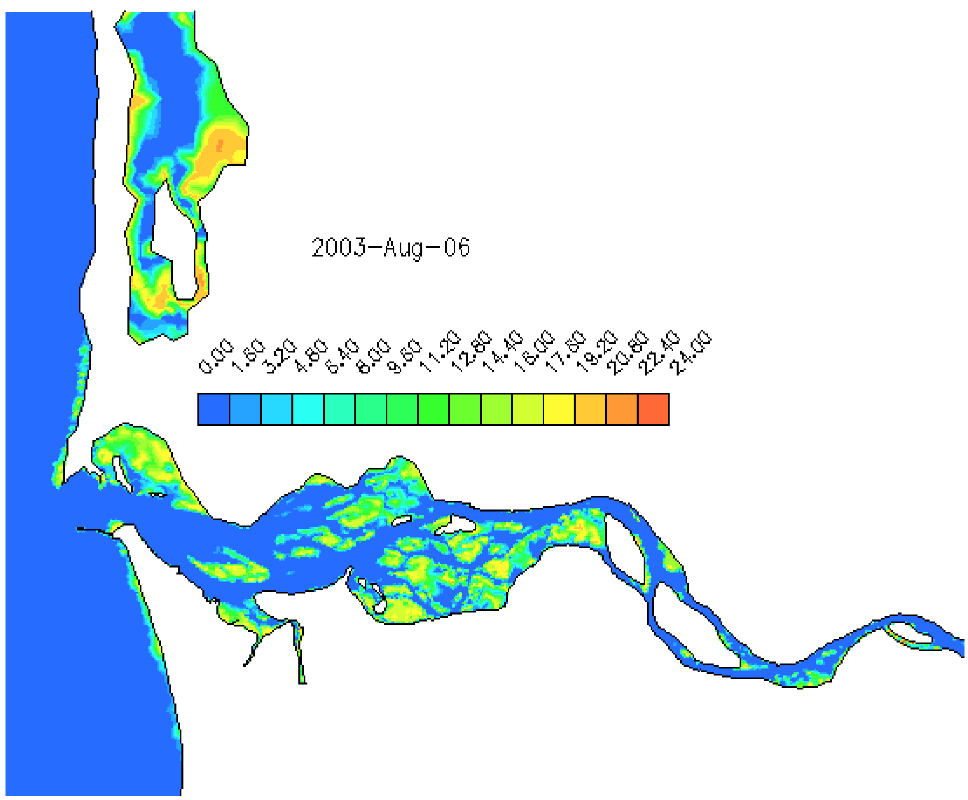

Figure 20. Habitat utilization potential (hours) for juvenile salmonids based on depth criteria during 6 August 2003.

2.3d Interpretation of observed change (2004 and beyond)

No activity during 2003.

2.4 Classify vegetation community structure at each wetland site

Vegetation community structure was characterized using the LCREP-generated classifications from remote sensing satellite (LANDSAT 7 ETM and panchromatic) and other data sources (CASI hyperspectral). These classifications and the delineation of discrete vegetation communities as habitat “polygons” will be verified and systematically sampled for vegetation composition by conventional analyses and for relative abundance using percent cover and other measurements (e.g., shoot density, above- and below-ground biomass) at each site.

In coordination with LCREP, we selected priority sample sites. Vegetation community samples were collected throughout the estuary and coincidental with Landsat 7 (ETM and panchromatic) and CASI (hyperspectral) data sources. We completed systematic measurements of vegetation samples to characterize community structure and composition at sample sites, and we provided vegetation results to LCREP for image classification and verification.

Vegetation communities at fish sampling sites were assessed using species frequency (presence/absence) and relative abundance. Sampling techniques and plot sizes differed between marsh, shrub-scrub and forested sites to accommodate differences in physiognomic (structural) diversity. To capture elevation-based heterogeneity in species composition at marsh sites, assemblages were assessed along a transect perpendicular to channel edge.

Objective 3. Characterize historical changes in flow and sediment input to the Columbia River estuary and change in habitat availability throughout the lower river and estuary.

No activity in 2003.